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Agricultural Capability Classification for Reclamation: Working Document



Heritage Fund



CONSERVATION AND
RECLAMATION COUNCIL
Reclamation Research
Technical Advisory Committee

Alberta's Reclamation Research Program

Regulating surface disturbances in Alberta is the responsibility of the Conservation and Reclamation Council. The Council Chairman is from Alberta Environmental Protection. The Council oversees a reclamation research program, established in 1978, to identify the most efficient methods for achieving acceptable reclamation in the province. Funding for the research program is provided by Alberta's Heritage Savings Trust Fund, Land Reclamation Program.

To assist with the development and administration of the research program, the Council appointed the inter-departmental Reclamation Research Technical Advisory Committee (RRTAC). Committee members represent the Alberta Departments of Agriculture, Food and Rural Development, Energy, and Environmental Protection, and the Alberta Research Council. The Committee updates research priorities, reviews research proposals, organizes workshops, and otherwise acts as the coordinating body for reclamation research in Alberta.

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**Agricultural Capability Classification
for Reclamation: Working Document**

by

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CAN-AG Enterprises Ltd.

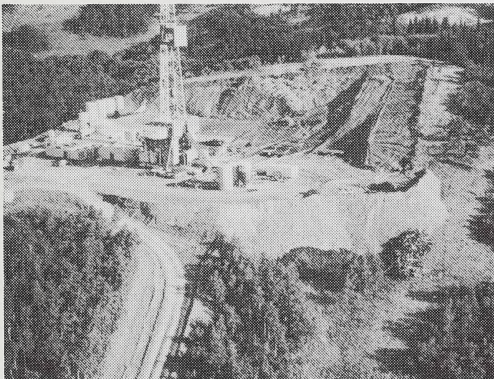
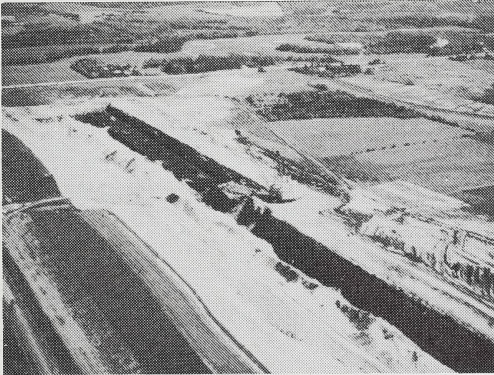
Prepared for

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DISCLAIMER

This report is intended to provide government and industry staff with up-to-date technical information to assist in the preparation and review of Conservation and Reclamation Approvals, and development of guidelines and operating procedures. This report is also available to the public so that interested individuals similarly have access to the most current information on land reclamation topics.

The opinions, findings, conclusions, and recommendations expressed in this report are those of the authors and do not necessarily reflect the views of government or industry. Mention of trade names or commercial products does not constitute endorsement, or recommendation for use, by government or industry.

REVIEWS

This report was reviewed by RRTAC, the Plains Coal Reclamation Research Program Committee and the Oil and Gas Reclamation Research Program Committee. RRTAC is also grateful to Dr. Wayne Pettapiece, Agriculture Canada for his review.

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PREFACE

The goal of land reclamation in Alberta is to create land capability equivalent to that which existed prior to disturbance. A primary requirement is to salvage all topsoil prior to disturbance and to replace it during the reclamation process. **Topsoil is defined as the uppermost mineral and organic soil materials which are valued as a growth medium.** It includes the A horizon (Ah, Ahe, Ap, optional Ae) as well as peat or organic litter (O and LFH horizons) to a depth of 50 cm. Other soil handling requirements are based on soil characteristics, landscape features, climate, and present and potential land use. These requirements are planned and implemented on a project-specific basis.

This classification system is a "tool" for assisting in the planning process and for evaluating agricultural land capability. It is based primarily on soils and landscape features, with climate included as an option. It is assumed that climate remains unchanged through the disturbance and reclamation period. One could evaluate reclamation success by comparing agricultural capability before and after disturbance.

The rating system provides the user the flexibility of addressing the three primary components, soil, landscape and climate, individually or in combination. The choice of how "equivalent capability" is determined, including "trade-offs" among components or classes, is made during the planning process.

Regardless of evaluation procedures used, successful reclamation is dependent upon re-constructing favourable growing conditions in the soil profile, with emphasis on the upper 50 cm. Key factors relating to root zone quality that are used in this system include: water holding capacity, organic carbon content, structure and consistence, salinity, sodicity, soil reaction, nutrient balance and moisture regime. The main landscape parameters include: slope, stoniness, pattern and erosion. Principal climatic factors are precipitation and temperature.

ACKNOWLEDGEMENTS

This project was sponsored by the Reclamation Research Technical Advisory Committee of the Alberta Land Conservation and Reclamation Council, with financial support from the Alberta Heritage Savings Trust Fund, Land Reclamation Program.

Special thanks to the many reviewers, from Government and Industry, who provided very valuable input throughout the course of this project. The cooperation of the following companies and their personnel for providing assistance, access and site data is also appreciated, with thanks: Consolidated Concrete Limited, Fording Coal Ltd., Luscar Ltd., Manalta Coal Ltd., NOVA Corporation of Alberta and TransAlta Utilities Corp.

Chairman's Note

This report is the result of several years of developing, reviewing and field testing a system to evaluate the capability of a reclaimed parcel of land for dryland, arable agriculture. Although the system has undergone a great deal of testing, we still view it as a working version. More testing is required to confirm the framework for the system and the values assigned to each of the parameters.

Specific issues that have been raised during the review and testing phases include:

- Does the rating for organic matter (topsoil) accurately reflect the value of this material for reclamation purposes?
- Will all users be able to evaluate the parameters (especially structure, colour, and layering/compaction) in the same manner as the author or each other? If not, will this affect the final rating?
- Is the effect of stones in subsoil accurately accounted for in the system? This is especially important for sand and gravel operations.

After you have used this system, please send us your comments and concerns. This will help us in later revisions to the system. When you send in your comments, we would appreciate you providing the site assessment forms and some information about the site and your specific (or general) concerns with applying the system to the site.

Please send your comments to:

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1. INTRODUCTION

This land classification system, which resembles the Canada Land Inventory capability classification (ASAC 1983; CLI 1965), is used to evaluate pre-disturbance and post-disturbance agricultural land capability for dryland farming. It is designed to aid in planning soil handling procedures and measuring land capability. Soil quality, landscape features, and average climatic conditions are quantified by assigning numerical ratings to individual components, then combining these to produce an overall rating. The system is intended for the agricultural zone of Alberta where disturbances are caused mainly by coal mining, the oil and gas industry, transportation, utilities and right-of-way construction. Soils are considered to be "clean" not contaminated with hydrocarbons, heavy metals, sterilants, herbicides, etc.

This capability evaluation applies to the upper one metre of soil. The soil capability rating of undisturbed soil is based on the natural soil horizons, notably the A, B, and C horizons. Similarly, the reclaimed soil profile is assigned three principal "horizons": topsoil (TS); upper subsoil (US); and lower subsoil (LS) (Figure 1).

Soil condition is a good indicator of soil productivity. Soil interaction with climate, physiography and management governs productivity by providing air, water, and nutrients to roots. Soil conditions are measurable based on technical data and professional judgement and are used to infer changes in productivity. A 15% reduction in inherent soil productivity potential is the target used for establishing threshold values between classes of soils. As a guideline, and given a similar level of inputs, Class 2 soils would have 15% lower yields than Class 1 soils, Class 3 soils would have 15% lower yields than Class 2 soils, and so forth. Yields on Class 4 soils are about half of those on Class 1 soils. These levels closely match those reported by Hoffman (1971) for common types of arable agriculture of CLI land capability classes 1 to 4.

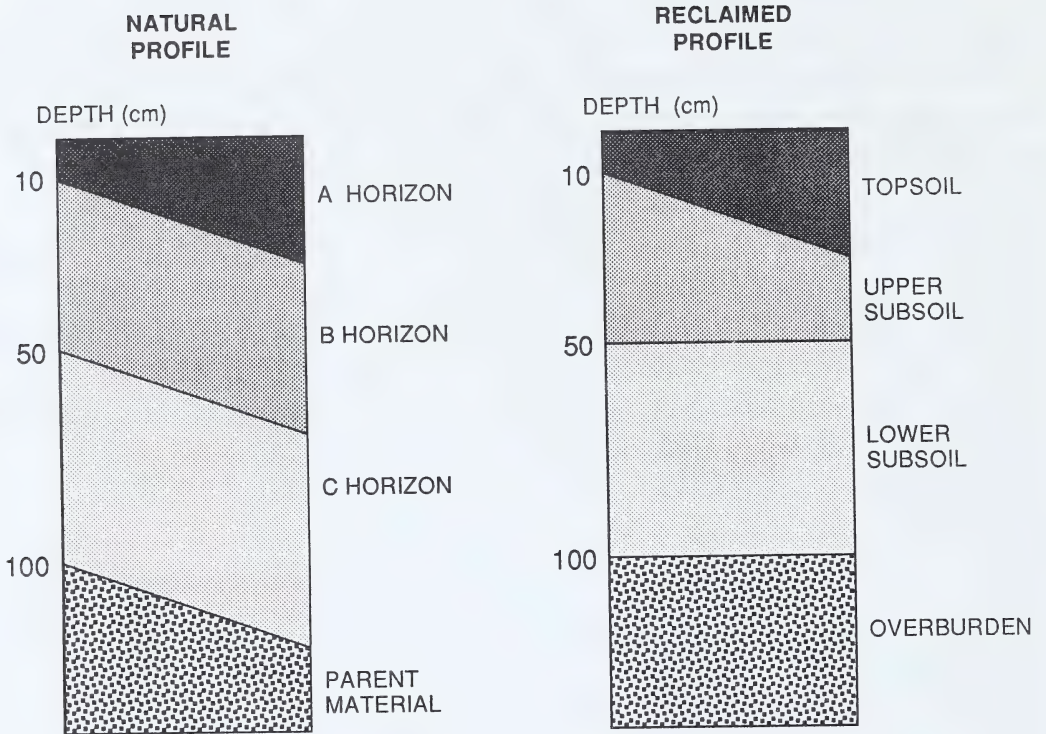


Figure 1. Schematic natural and reclaimed soil profiles.

2. SYSTEM DEVELOPMENT

2.1 FRAMEWORK

This dryland agricultural capability classification for reclaimed lands is based primarily on soil, landscape and climatic components. It closely follows the format of the "Land Capability Classification for Arable Agriculture in Alberta" (ASAC 1987a) for determining land capability. Inventory requirements are also specified, based on modification of the guidelines presented in the "Soil Quality Criteria Relative to Disturbance and Reclamation" (ASAC 1987b).

Reclamation success is dependent upon favourable conditions in the root zone for optimum crop growth. Soil parameters influencing growth can be quantitatively measured, and these measurements are integrated to estimate the sustained productivity of reclaimed lands. Key soil factors relating to root zone quality include: water holding capacity, organic carbon (humus) content, structure and consistence, salinity, sodicity, soil reaction, nutrient balance and moisture regime. The main landscape factors include: slope, stoniness, pattern and erosion. Climatic factors considered are temperature and precipitation.

Each component; soil, landscape and climate, is given a numeric rating derived from values assigned to defined categories for all the key factors mentioned above. Soils are evaluated on the basis of three principal layers: topsoil (TS, A or O horizon), upper subsoil (US or B horizon), lower subsoil (LS or BC, C horizons) and soil moisture regime. The climatic moisture index and degree of soil wetness are used in determining the point deductions for soil moisture regime. Landscape factors are rated the same in reclaimed and undisturbed lands. Ratings for climatic conditions after reclamation are assumed to remain the same as before disturbance, therefore, climate ratings are optional. Procedures for rating climate are adapted from the Land Capability Classification for Arable Agriculture in Alberta (ASAC 1987a) are appended (Appendix, Section 9.2).

This rating system is limited to 1 metre depth, although material characterization below 1 m is recommended to help in predicting sustainability as deeper materials may affect soil performance. Replacement of deeper subsoil materials may be desirable. For rating purposes, the rooting depth is 1 m and the relative contribution of various depths within the root zone to the productivity of the soil is based on root distribution and water uptake during the growing season. Crops growing in a uniform undisturbed soil, under irrigation, take up water in the proportion 40:30:20:10 from successive 25 cm increments of the 1 m root zone, as graphically portrayed in Figure 2 (Withers and Vipond 1980). Hausenbuiller (1985) reported that extraction patterns for shallow (turf grasses), medium (cereals), and deep rooted (alfalfas) crops are such that 80% or more of their water is derived from the 30 cm, 60 cm and 90 cm zones, respectively.

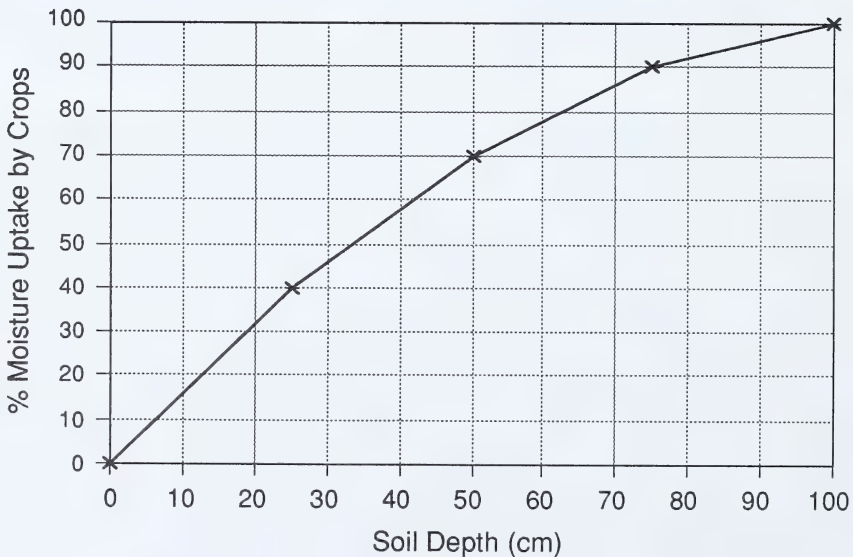


Figure 2. Relationship between crop water uptake and soil depth.

Crops growing in normal, uniform, nonlimiting soils take up about 70% of their moisture from the upper 50 cm and 30% from the 50 to 100 cm depth layer; hence, this ratio and depth is used to rate available water holding capacity. It is estimated that in the 25 to 50 cm zone, typically upper subsoil, moisture extraction is 1.2% of total requirements per cm, and in the 50 to 100 cm zone it averages 0.6% of total requirements per cm, or about 2:1 for upper to lower subsoil. Consequently a 2/3:1/3 multiplier is used in rating all parameters of upper subsoils (B horizon) and lower subsoils (BC, C horizons), respectively.

Guidelines for rating natural and reclaimed soils follow and are illustrated in Figure 3.

1. Rate topsoil based on depth available (Figure 3a) or; if topsoil is less than 10 cm deep use the mixed 10, 15 or 20 cm surface layer (match depth of Ap in natural cultivated soils in the area) using topsoil criteria (Figure 3b) or; if topsoil is deeper than 35 cm, then subsoil is treated as one subsoil layer (Figure 3c).
2. The upper subsoil (B horizon) underlies the topsoil, it is at least 15 cm thick and extends to 50 cm from the surface. Lower subsoil continues below the upper subsoil, to 100 cm deep.

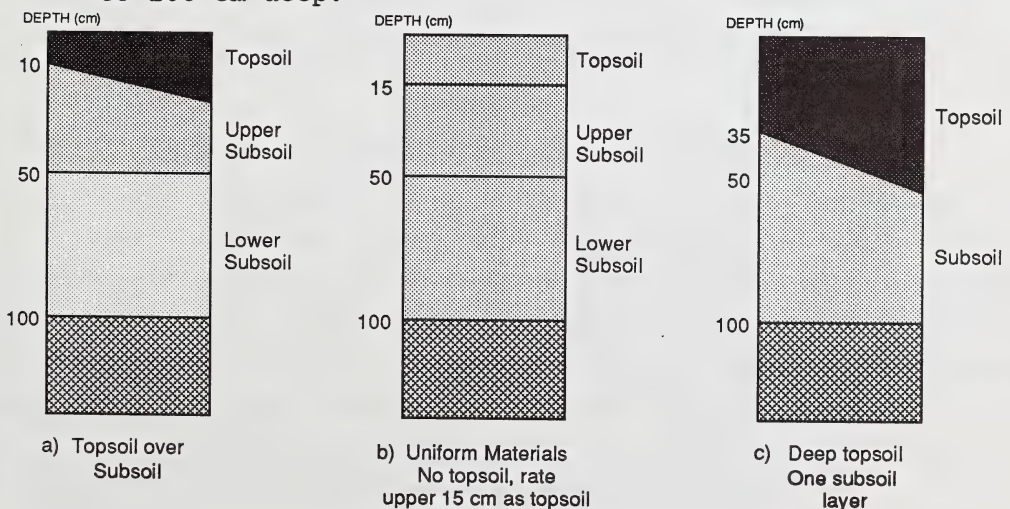


Figure 3. Horizon designations for reclaimed soils.

2.2 APPROACHES AND ASSUMPTIONS

A dryland agricultural capability classification approach to the rating of reclaimed land is used. Definitions as used in this report are:

Land capability - the ability of the land to support a given land use, based on an evaluation of the physical, chemical and biological characteristics of the land, including topography, drainage, hydrology, soils and vegetation.

Soil capability for agriculture - the nature and degree of limitations imposed by the physical, chemical and biological characteristics of a soil unit for crop production.

Arable - tillable; agricultural production based on cultivation practices; land that is cultivated or is suitable for cultivation. Arable is used in contrast to agriculture based on grazing (non-cultivated) systems.

Land - means terrestrial, semi-aquatic and aquatic landscapes when the term is used in the definitions of "land capability" and "equivalent land capability".

Dryland (rainfed) - an agricultural system based on natural precipitation - in contrast to irrigated systems.

Basic concepts of the Land Capability Classification for Arable Agriculture in Alberta (ASAC 1987a) were adopted. Class 1 has the highest capability (least limitations for production and management) for dryland arable agriculture and Class 7 has the lowest capability (most severe limitations) (see Table 1). Assumptions are:

1. It is an interpretive system based on limitations for dryland arable agriculture and general productive capacity for common field crops, including small grains (wheat, barley, oats),

- oilseeds (canola, flax), other arable crops (peas, beans, lentils) and grasslands (hay, pasture).
2. Good soil management practices under a largely mechanized system of agriculture are assumed. Recommended minimum field size is set at 16 ha (40 acres). Deductions are assigned if <16 ha.
 3. Lands in each class are similar in degree, but not necessarily in kind, of limitations for arable agriculture.
 4. Lands are classified according to continuing limitation, assuming improvements to minor problems will be made, for example, minor drainage and stone and root removal.
 5. The capability classification could change with major changes in such features as reclamation, levelling, land use or drainage schemes.
 6. Economic factors such as distance to market, farm size or grain market prices are not considered.
 7. Point deductions may change as additional research and testing is conducted.
 8. The soils are not contaminated with hydrocarbons, heavy metals, sterilants, etc.

Table 1. Relationship of capability class to index points.

Capability class	Index points	Limitation
1 ^a	80-100	none to slight
2	60-79	slight
3	45-59	moderate
4	30-44	severe (marginal)
5	20-29	very severe
6	10-19	extremely severe
7	0-9	not useful for agriculture

^a Optional to use prefix R for reclaimed land.

The major components - soil, landscape and climate - are considered separately and each is assessed a value between 0 and 100. In natural areas the final rating is, conventionally, based on the most limiting of the three. In reclaimed land settings, this rating system provides the user a choice of using the individual components, the most limiting of soil and landscape components, or the most limiting of the three components, to attain the "equivalent capability". The system also identifies specific limiting factors and the relative contribution of each. Climate is accepted as is, but soils and landscape features can be upgraded through specific management strategies. Identification of one or two major limitations is recommended (each serious enough to downgrade one or more capability class).

Some factors are more important than others, as reflected by the ratings:

1. The entire point deduction range of 0 to 100 is not used for all parameters.
2. Some factors are modifiers to a base rating and are treated as percentage rather than absolute deductions, such as, subsoil limitations.
3. Class limits are narrower at the lower ratings.
4. When reading maps to determine moisture or energy indexes, interpolate to the nearest 50 units using the shortest distance to the nearest isolines. When reading other charts, interpolate between values on a linear basis, and round off the values.

2.3 SYSTEM DESCRIPTION

This evaluation procedure parallels The Land Capability Classification for Arable Agriculture in Alberta (ASAC 1987a), and the original CLI (1965) system, permitting general comparison of land capability with adjoining lands. There are seven classes of land, rated according to potential and limitations for

agricultural use. The top three classes are capable of sustained production of cultivated crops, while the fourth is marginal. The classes are an assessment of the degree or intensity of limitation. For example, Class 3 land has limitations which are more severe and may be different than Class 2. The subclasses describe the kind of limitations responsible for class designation. Such information is useful in land-use planning, soil handling for reclamation and subsequent land management.

2.3.1 Land Capability Classes

- Class 1 (R1) - No significant limitations for crop production (80 to 100 index points).
- Class 2 - Slight limitations that restrict the range of crops or require modified management practices (60 to 79 index points).
- Class 3 - Moderate limitations that restrict the range of crops or require special management practices (45 to 59 index points).
- Class 4 - Severe limitations that restrict the range of crops that can be grown or require special management practices (30 to 44 index points).
- Class 5 - Very severe limitations for sustained arable agriculture. Annual cultivation using common cropping practices is not recommended with grazing as the only potential (20 to 29 index points).
- Class 6 - Very severe limitations for arable agriculture with no cropping; used only for grazing (10 to 19 index points).
- Class 7 - No capability for arable agriculture (0 to 9 index points).

2.3.2 Land Capability Subclasses

A subclass is a grouping of lands with the same kinds of limitations, as follows:

Mineral soils (S)

- moisture availability (M)
- structure/consistence (D)
- organic carbon mass (F)
- acidity/alkalinity (V)
- salinity (N)
- sodicity/saturation percentage (Y)
- nutrient balance (K)
- peaty surface (O)
- topsoil loss (G)
- moisture regime factors (W)
 - wetness
 - climatic droughtiness

Landscape (L)

- slope and length (T)
- surface stoniness (P)
- pattern and field size (J)
- erosion (E)

Climate (C)

- moisture limiting factor (A)
- temperature limiting factor (H)

3. INVENTORY REQUIREMENTS

To use the rating system, data (observations, measurements or estimates based on professional experience) are required for each of the identified factors within the soils, landscape and climate components. Some values can be estimated from maps and reports while other data are collected by site inspection. The level and purpose of the capability rating also has a bearing on the detail required, with regional assessments generally satisfied by estimates from published data but assessment of individual land parcels requiring detailed site investigations.

3.1 CLIMATE DATA

Climatic rating may be assigned from provincial maps included in this report (Section 9.2) based on long term records (usually 1951-80 normals). If documented local data are available, the assessor has the option of adjusting the parameters as applicable, such as modification for excess spring and fall moisture, hail index and fall frosts.

3.2 SOIL SURVEY

Soil and landscape data are more site specific than the climate requirements and must be collected in the field. The definition and descriptions of individual parameters for natural soils follow standards presented in The Canada Soil Information System: "Manual for Describing Soils in the Field" (Expert Committee on Soil Survey 1983) and "The Canadian System of Soil Classification" (Canada Soil Survey Committee 1978).

Descriptions of some important parameters vary in disturbed soils, hence, the need to define "equivalent" ratings. Regional soil survey reports and maps prepared by Alberta Soil Survey (Alberta Research Council, Agriculture Canada, University of Alberta) provide the most comprehensive set of soil and landscape data. Similar information is collected by the Resource Evaluation and Planning Division, Alberta Environmental

Protection and the Land Classification Branch of Alberta Agriculture, Food and Rural Development. Private sector soils reports, development and reclamation plans, and aerial photographs should also be consulted where applicable.

The basic feature of soil survey maps is that similarly identified areas have the same characteristics and are therefore predictive. This makes soil surveys and the interpretations useful in the reclamation process in four specific areas:

1. Land Use Planning - Plan preparation that affects the use of the land considering suitability and limitations for various agricultural uses.
2. Soil Handling - The selective salvage, conservation and replacement of materials of differing quality, in a manner that meets planning objectives.
3. Soil Management - The conditioning of the land for cropping, pasture or other agricultural uses.
4. Land Capability Evaluation - Determines whether the reclaimed land meets the objective of the reclamation plan, or meets equivalent capability.

Equivalent land capability means the ability of the land to support various land uses after conservation and reclamation is similar to the ability that existed prior to an activity being conducted on the land, but that the individual land uses will not necessarily be identical.

3.2.1 Design

Soil surveys are planned or designed as follows:

1. Establish the objectives. Baseline soils mapping should provide information on the types of soils present, in sufficient detail, to permit decision making regarding optimum site location, materials, handling and post disturbance soil reconstruction.

2. Determine the smallest area in the field to be described and delineated and which can be read by users. The ECSS (1981) recommends that a minimum size delineation on a soil survey map is 0.5 cm^2 . For linear features this corresponds to 0.5 cm.
3. Determine the survey intensity level (SIL). SIL is defined as the required number of field inspections per unit area or other estimates of accuracy. SIL is based on inspection densities, scale, survey techniques, levels of soil taxonomy used, and accuracy of boundaries. Level 2 surveys are conducted to aid in general planning. Level 1 surveys are conducted for specific operations tailored to the type of activity. Table 2 provides suggested scale limits for the two intensity levels defined and Table 3 provides recommended scales for mapping. The scale of mapping is based mainly on the minimum size of field delineation. For example, if soil units with different use potentials must be recognized down to a size of 4 ha then the scale should be at least 1:20 000. Minimum field size (rectangular) for a farmable unit is set at 16 ha (40 acres): capability rating for fields <16 ha is reduced under landscape pattern. Where reclaimed areas are <16 ha, very detailed mapping is recommended (suggest a minimum of 25 inspections, also inspect adjoining undisturbed lands at a minimum of 10 sites per major soil type, for comparison where baseline information may be unavailable). For post-disturbance mapping, a scale of 1:5 000 is suggested for non-selectively handled areas or where materials handling techniques were minimal. Where selective handling techniques are employed a scale of 1:10 000 is recommended.

Table 2. Criteria for identifying survey intensity levels^a.

Survey Intensity Level (SIL)	Common Name	Definitive Characteristics		Associated Features		Appropriate Scale (Usual) ^c
		Inspection Intensity	Methods of Investigations	Main Kinds of Soil Components	Map Units ^b	
SIL1	very detailed	At least one inspection in every delineation (1 per 1 to 5 ha). A minimum of 25 per area at small reclaimed sites (<16 ha). Boundaries observed throughout entire length. Where baseline data are inadequate, check at least 10 control sites.	Transects and traverses less than 0.5 km apart. Profile descriptions and samples for all soils.	Series or phases of series	Mainly simple units	1:14 000 or larger (1:5 000)
SIL2	detailed	At least one inspection in 90% of the delineations (1 per 2 to 20 ha). Boundaries plotted by observations and interpretation of remotely sensed data verified at closely spaced intervals.	Transects and traverses less than 1.5 km apart. Profile descriptions and analyses for all major soils.	Series or phases of series	Simple and compound units	1:5 000 to 1:40 000 (1:20 000)

^a Adapted from a Soil Mapping System for Canada: Revised (ECSS 1981).^b Simple units have over 80% of a single component or a nonlimiting inclusion. Compound units are complexes or associations of two or more components.^c Appropriate publication scale.

Table 3. Guidelines for conducting soil surveys relative to development and reclamation in the Plains Region.

Mapping Land Areas	Purpose	Level of Survey	Recommended Publication Scale	Min. Size Area Represented by	Inspection Density	Sampling Density	Overburden Sampling (optional)
				1 cm ² on Map (ha)	(ha/Insp)	(Profile, Sites) ha/sample	ha/sample Site
Baseline		2	1:10 000	1	1 to 5	10 to 50	150 to 300
Post-Disturbance (Nonselective Handling ^a)		1	1:5 000	0.25	0.25 to 1.25	1.25 to 6.25	--
Post-Disturbance (Selective Handling ^a)		1	1:10 000	1	1 to 5	10 to 50	—
Mapping Linear Corridors							
				1 cm on Map	Insp/km	Sites/Soil	Sites/Soil
Baseline		1	1:10 000	100 m ^b	5 ^c	1 to 5	1 to 5
Post-Disturbance		1	1:10 000	100 m ^b	5 ^c	1 to 5	1 to 5
Mapping Sites (<16 ha)							
				1 cm ² on Map (ha)	(ha/Insp)	(Profile, Sites) ha/sample	ha/Sample Site
Baseline		1	1:1 000	0.1	<1 ^d	<5	<5
Post-disturbance		1	1:1 000	0.1	<1 ^d	<5	<5

^a Nonselective Handling. Soil materials excavated and replaced without selective handling, that is, salvaging better materials.

Selective Handling. Soil materials excavated, stored or transported, and replaced in a planned manner to salvage better quality materials. Areas of different materials, depths, and handling procedures are known, in accordance with reclamation plans.

^b For similar map units 100 m is minimum, for contrasting units 25 m is the suggested minimum or a symbol notation may be used.

^c This includes a minimum of two descriptions to depth of disturbance (e.g. trench depth) and three to 50 cm (A and B horizon).

^d At small areas such as well-sites or gravel pits where pre-disturbance mapping is not available, a minimum of 25 inspections within the disturbance and a minimum of 10 on the adjoining undisturbed land is suggested to compare pre- and post-disturbance quality.

3.2.2 Soil Profile Characteristics and Landscape Features

Soil mapping involves the recognition of soil profile characteristics and landscape features. Morphological characteristics of the soil profile normally include:

1. horizon thickness and sequence;
2. colour;
3. texture;
4. structure (aggregate size and strength);
5. consistence;
6. effervescence and salt crystals;
7. coarse fragments;
8. field pH (not required for all observation sites);
9. presence of mottles; and
10. roots (abundance, depth, pattern).

To complete a site description include the following:

1. slope class (topography), length and position;
2. aspect;
3. landform and parent material;
4. stoniness;
5. surface and internal drainage;
6. extent of erosion;
7. present land use (as related to delineated soil types); and
8. vegetation cover - trees, shrubs, herbs, grasses, and mosses (as related to delineated soil types).

Not all of the above need to be recorded at each inspection site, but they should be documented for each profile sampling site. Parameters recorded will vary relative to the type of disturbance involved.

3.2.3 Map Presentation

It is advantageous to present the survey information on an aerial photo mosaic base.

3.3 SOIL SAMPLING

Methods of sampling vary with purpose. Sampling intensity is dependent on the scale of mapping used, variability of the soils in the survey and components to be analyzed.

3.3.1 Sampling for Baseline Evaluation Purposes

The number of sampling sites selected is determined by the frequency of the individual map units. Sufficient samples are to be collected to properly characterize the map units (Table 3).

In baseline mapping, the samples are required for characterization and classification. Sampling intensity refers to sampling of soil pits. Some "grab" samples of surface materials may be collected and included in the recommended number of sampling sites. For baseline purposes, at least 50% of the sampled sites should be to 1 m depth.

Table 3 provides a range in the sampling density required for a particular scale. For example, in a Level 2 survey conducted at a scale of 1:10 000, a density of one site per 10 to 50 ha is recommended.

3.3.2 Methodology of Sampling for Baseline Purposes

The following procedure for baseline evaluation purposes is recommended:

1. select sample sites typical of the soils that the samples are intended to represent (McKeague 1978);
2. sites should be away from fences, roads and other features that may cause abnormal properties;
3. samples should be collected from freshly dug pits or cuts. The pit should 1 m deep, or to the bottom of the control section (CSSC 1978), whichever is deeper.
4. sample on a horizon or "homogeneous layer" basis and from a face about 50 cm wide for laterally uniform soils. If horizons are discontinuous, or

vary greatly in thickness or degree of expression, collect samples from different locations on the pit face to ensure a representative sample of each horizon. Some discontinuous horizons may not be significant enough in amount or characteristics to warrant sampling and analysis;

5. start sampling at the bottom of the pit.

3.3.3 Overburden Sampling (1 m + Depth)

The preceding section dealt with sampling the soil control section which in the case of mineral soils is a depth of 1 m. The material below the control section and above the resource to be extracted is overburden.

Overburden sampling is determined during the planning process. It should be based on the lithology of the area, with selection of sites based on soils and geologic information. As a guideline, samples should be taken at 1 to 2 m intervals down to the resource, at 2 or more locations per "overburden mapping unit". Surficial and bedrock geologic information is available for most areas of the province.

3.3.4 Sampling Post-Disturbance Areas

Sampling of reconstructed soils should be done on the basis of layers or materials such as topsoil, upper and lower subsoil, and on depth intervals within each of these layers (Table 4).

Table 4. Sampling depth intervals for reconstructed soils.

Material	Depth Interval(cm)	Notes
Topsoil	0 to 15 (minimum 10 cm)	The topsoil layer should be taken in one sample. If topsoil depth is less than 20 cm then that depth of material should be segregated from material below. If topsoil layer is greater than 20 cm in thickness sample two intervals. (Note that more detailed sampling is usually required for contaminated soils.)
Upper Subsoil	20 to 50 (minimum 15 cm)	The upper subsoil sampling interval is the minimum suggested. If materials are variable, differing strata should be sampled separately.
Lower Subsoil	50 to 100	The lower subsoil sampling interval is the minimum suggested. If materials are variable, differing strata should be sampled separately.

3.3.5 Transporting and Processing Samples

Precautions to follow:

1. Polyethylene plastic bags should be used for transporting samples from the field. (Special storage and treatment procedures are necessary for some contaminated samples. Receiving laboratories should be contacted prior to sampling for instructions on special procedures.)
2. Galvanized equipment should be avoided if zinc is to be determined.
3. Moist samples to be analyzed for nitrate or ammonium nitrogen must be kept chilled.
4. Moist or wet samples must be frozen or spread to dry on waterproof material. When dry store in water-tight containers.

3.4 STATISTICAL ANALYSIS

Statistical procedures are not defined as part of the rating system. Calculation of means, ranges and variances of properties for key soil types are helpful but optional. Transect methods may be used to define map unit homogeneity.

3.5 ANALYTICAL REQUIREMENTS

Analytical requirements are separated into those required for baseline characterization (Table 5) and those required for disturbed areas (Table 6). The recommended sampling intensities generally apply to sizeable blocks of land (>16 ha). In small areas such as wellsites, or along linear features such as pipelines, recommended inspection and sampling intensities are defined in published provincial guidelines.

The analyses help to characterize soils for classification, mapping and making interpretations relative to the quality of the soils in the undisturbed and reconstructed states. Emphasis is on particle size distribution and identifying materials unsuitable due to excessive levels of salinity, sodicity or pH. Fine textured sodic and saline-sodic materials are common in Alberta and will restrict plant growth if they are near the surface.

Analyses to quantify other soil characteristics are required less often. Bulk density, penetrometer resistance, permeability and clod size distribution data are recommended in calibrating field descriptions of subsoil structure in disturbed soils. Cation exchange capacity, total carbon and macronutrient analyses are useful in assessing availability, balance and mobility of some nutrients. Extractable aluminum and manganese analyses are useful on low pH soils in toxicity assessment.

Table 5. Minimum analytical requirements for soil characterization.

Analysis required on all samples, including topsoil within 20 cm (A horizon), upper subsoil at 20 to 50 cm (B horizon), and lower subsoil at 50 to 100 cm (BC, C horizon). These depths may be altered to suit layering or horizonation.

Analyses	Notes	Preferred ^a Method	Acceptable Method
pH	If one is interested in soil pH only, method 3.11 provides a number of advantages (p. 66, McKeague). However, the saturation extract (method 3.14) is also used for EC and soluble ion analysis.	3.14 or 3.11	3.13
Saturation ^b Percentage	(i) Samples which need to be resaturated after equilibrating for four hours may be resaturated but must be equilibrated for a further four-hour period prior to extraction. This step may have to be repeated several times to achieve saturation. (ii) If the saturated soils cannot be filtered under normal vacuum, make a note of this and report the pH and saturation % only.	3.21	
Electrical Conductivity ^b		3.21	
Soluble Cations ^b (Ca, Mg, Na, K) and SAR		3.21	
Particle Size Distribution		2.11	2.12

^a McKeague, J.A. 1978. Manual on soil sampling and methods of analysis. Canadian Society of Soil Science. Ottawa, Canada.

^b In profiles where there is no evidence of salinity and sodicity these analyses are not required, but are recommended on selected samples to confirm absence of salts.

Table 6. Selected additional analyses for soil characterization.

Analysis required on selected samples from at least two representative profiles (topsoil and upper subsoil or A and B horizons) per major soil type or map unit.

Analyses	Notes	Preferred Method	Acceptable Method
Organic Carbon ^a (topsoil)	3.611	3.612/3.613	
Cation Exchange ^b Capacity	Not required for samples containing free carbonates, carbonates or crystals of soluble salts	Methods of Soil Analyses, Agronomy No. 9 2nd Edition ^c	3.32
Exchangeable ^b Cations (Ca, Mg, Na, K)	Not required for samples containing free carbonates or crystals of soluble salts	3.321A	
Bulk Density ^d	To calibrate estimates.		

^a The methods listed make no mention of auto analyzers, specific ion electrodes or ICP units. Methodologies associated with these types of equipment would be acceptable. (Note that other techniques may be preferable for contaminated soils.)

^b Cation exchange capacity and exchangeable cation determinations are done primarily to confirm classification of the soils.

^c Rhoades, J.D. 1982. Cation exchange capacity. IN: Methods of Soil Analyses, Part 2, Chemical and Microbiological Properties, 2nd Edition. A.L. Page (ed). Published by America Society of Agronomy and Soil Science Society of America, Madison, Wisconsin, USA. pp. 152-154.

^d This determination optional, useful for calibration of visual estimates. Method is given in Sheldrick (1984).

Continued...

Table 6. Concluded.

Analysis required on selected samples from two representative profiles (topsoil and upper subsoil or A and B horizons) per major map unit.

Analyses	Notes	Preferred Method	Acceptable Method
Gypsum ^a	(i) Gypsum may be estimated from the lesser of the Ca or SO ₄ concentration having a specific conductance less than 2 dS/m in the saturation extract. (ii) The 5/1 (solution/soil) ratio recommended in the preferred method may be insufficient to extract all the gypsum present. Use a ratio large enough to produce a filtrate with a specific conductance less than 2 dS/m.		
Calcium Carbonate Equivalent	Samples may be screened on the basis of pH. Any sample having a CaCl ₂ pH of 6.5 or greater or any sample having a "water pH" of 7.2 or greater should be analyzed for CaCO ₃ .	3.43	Methods of Soil Analyses, Agronomy No. 9 ^b
Aluminum and Manganese-Extractable	Not required if sample pH is greater than 5.5 (water pH)	4.64	

^a Not required in areas where salinity and sodicity are not a problem.

^b Black, C.A. et al. 1965. Methods of Soil Analysis, Part 1. Part 2, Chemical and Microbial Properties, Agronomy No. 9. America Society of Agronomy, Inc., Madison, Wisconsin, USA. Calcium carbonate equivalent - Chapter 91 on Carbonate by L.E. Allison and C.D. Moodie, Acid Neutralization Method (91-4). pp. 1387-1388. Note that the estimate of carbonate provided by this procedure will usually be somewhat high because constituents other than carbonate can react to some degree with the acid utilized.

4. FACTORS FOR MINERAL SOILS

Rating of mineral soils is considered in four parts; topsoil or surface soil, upper subsoil (below topsoil to 50 cm), lower subsoil (50 to 100 cm), and moisture regime. Emphasis is on topsoil or, if absent, the surface soil (generally 10 to 20 cm deep depending on farm cultivation practices and natural soil conditions in the area). The surface rating is the basic soil rating assessed by point deductions; subsurface and moisture regime factors are percentage modifiers.

4.1 SURFACE FACTORS

Nine parameters are characterized: moisture availability (in the 100 cm profile) which is related to texture; topsoil structure/consistence; organic carbon mass based on percentage, depth and bulk density of topsoil; soil reaction; salinity; sodicity; nutrient imbalance; peaty surface; and topsoil loss (where applicable). In reclaimed agricultural lands the minimum thickness of the topsoil (Ah, Ahe, Ap, optional Ae) is 10 cm. The Ae is to be salvaged where it contributes to an equal or better soil rating than if it were not salvaged. If topsoil is absent, rate the upper 10, 15, or 20 cm, whichever depth best matches depth of cultivation on natural agricultural lands in the area.

4.1.1 Moisture Availability Based On Texture: Subclass M

The amount of water available is a prime factor governing crop production. The main controlling soil factors are depth and texture. Determine the water holding capacity in the 100 cm profile using Table 7, apply the weighting as shown to reflect more importance of the upper root zone (0 to 50 cm depth) and assign point deduction from Figure 4. The following equation and example demonstrates the procedure for rating available water holding capacity (AWHC) for a profile with 20 cm of SL over CL.

$$\begin{aligned} \text{AWHC (mm/100 cm)} &= (70\% \times \frac{\text{AWHC}}{0-50 \text{ cm}} + 30\% \times \frac{\text{AWHC}}{50-100 \text{ cm}}) \quad 100 \text{ cm profile} \\ \text{or} &= [70\% \times \text{AWHC (upper 50 cm)} + 30\% \text{AWHC (lower 50 cm)}] \times 2 \end{aligned}$$

$$\begin{aligned} 20 \text{ cm SL} / 80 \text{ cm CL} &= [(70\% \text{AWHC @ } 0-50 \text{ cm}) + (30\% \text{AWHC @ } 50-100 \text{ cm})] \times 2 \\ \text{AWHC} &= \{70\% [(20 \text{ cm SL @ } 1 \text{ mm/cm}) + (30 \text{ cm CL @ } 1.7 \text{ mm/cm})] \\ &\quad + 30\% [50 \text{ cm CL @ } 1.7 \text{ mm/cm}]\} \times 2 \end{aligned}$$

$$\text{AWHC} = [70\% (71) + 30\% (85)] \times 2 = 150 \text{ mm.}$$

Figure 4, which relates profile water holding capacity to point deduction, indicates that for this example the deduction is 0 points.

The amount of water available to plants is also a function of the regional climate. For example, limited soil moisture storage, inhibited rooting or other restrictions are all magnified in a drier climate. This is reflected in the final step of the soil rating procedure which links the soils and precipitation - potential evapotranspiration factors through the moisture regime adjustment.

Table 7. Relationship between texture and water holding capacity.

Texture	Total Available Moisture (mm)	
	mm/cm ^a	0 to 100 cm
Gravel	0.2	20
Sand	0.4	40
Loamy sand	0.6	60
Sandy loam	1.0	100
Loam, sandy clay	1.5	150
Sandy clay loam	1.5	150
Clay loam	1.7	170
Silt loam, silt	1.8	180
Clay	1.9	190
Silty clay loam	2.0	200
Silty clay	2.25	225
Heavy clay	2.25	225
Peat	1.5	150
Gravelly (deduct 0.1 mm/cm from texture, or 10 points from 1 m)		
Peaty (add 0.1 mm/cm to texture, or 10 points for 1 m)		

^a These values can be used to determine total available moisture in a soil with layers of different textures. Moisture available in mm/cm for a specific texture times thickness of layer in cm + moisture available for texture times thickness next layer, etc.

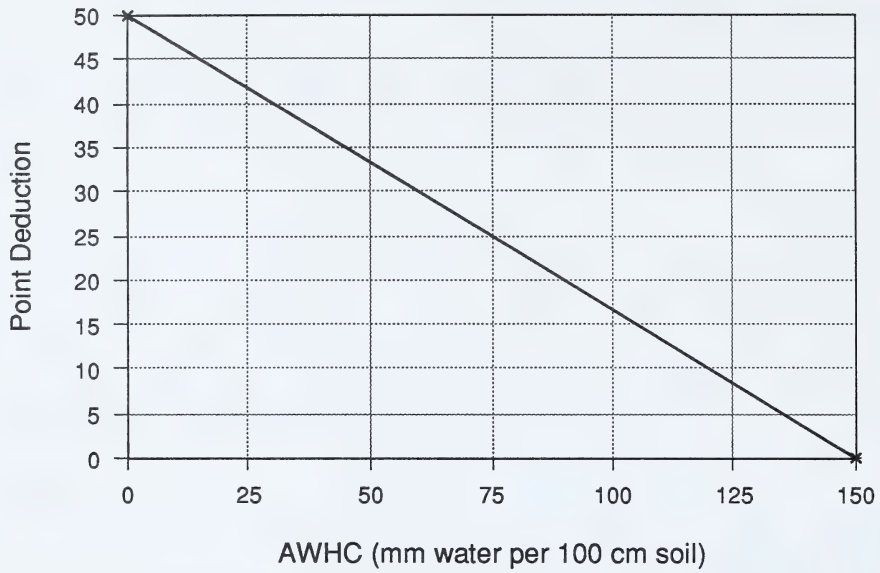


Figure 4. Point deduction for profile water holding capacity.

4.1.2 Structure/Consistence: Subclass D

Structure, the aggregation of soil particles, is important to water permeability, aeration, tilth and workability. It is described in terms of the size and shape of aggregates, and it is influenced by texture and organic matter content. An associated term is consistence, the resistance to crushing, which depends on stability of aggregates, bulk density and compactness. Relationships between structure, consistence, texture, bulk density and deductions for plant growth are shown in Table 8 and additional information is given in Section 9.1. This factor is restricted to a maximum 30 point deduction in the surface soil rating because management can modify surface features in cultivated soils.

Table 8. Point deductions for surface soil structure and consistence categories.

Structure ^a	Dominant Size peds/aggregates	Consistence ^a moist/dry	Points Deducted
granular	<5 mm	very friable/soft;	0
granular, subangular	5 to 10 mm	friable/slightly hard;	5
powdery, single grain	<2 mm	loose/loose;	10
platy	<5 mm	hard or loose;	
crusted surface	variable		
medium blocky ^b	10 to 20 mm	firm/hard;	20
coarse blocky	20 to 100 mm	very firm/very hard;	
cloddy			
massive	>100 mm	extremely firm/ extremely hard	30

^a Deduct points based on the most limiting condition, either structure or consistence.

^b In the absence of topsoil or organic enriched materials, subsoils at the surface which are loams to clay loams are usually given a 20 point deduction, whereas clays are usually assigned a 30 point deduction.

4.1.3 Organic Carbon and Topsoil Depth: Subclass F

All topsoil should be salvaged. Topsoil, and especially organic carbon (humus), is a very important component of all, contributing to biological activity, the nutrient pool (mainly nitrogen), structure, tilth, workability, water holding capacity, and resistance to erosion.

Organic content is measurable in the laboratory or in many cases it can be estimated by soil colour. The "value" component (the darkness or gray component) of the Munsell Soil Colour notation correlates well with percentage organic carbon in a dry soil as shown in Table 9 and Figure 5. Where the Ap horizon is less than 10 cm thick the dry colour of the upper layer (10, 15 or 20 cm to match depth of cultivation on natural soils) is used to estimate the organic carbon content. In the absence of a dry colour, increase the "value" of a moist colour by 1 unit to approximate the dry value (suggest this relationship be tested and supporting documentation be provided when this approach is used).

Table 9. Estimation of topsoil organic carbon content.

% Organic Carbon	% Organic Matter ^a	Dry Munsell value ^b	Colour
≥6	≥10.7	2/x ^c	black
4-5	7.1-8.9	3/x ^d	black
3	5.3	4/x	dark brown
			dark gray
2	3.6	5/x	brown; gray
1	1.8	6/x	gray
<1	<1.8	7/x	light gray

^a Organic carbon % x 1.78 = organic matter %

^b Standard soil horizon designations. For example, a dry Ap colour of 10 YR 4/4 has 3% organic carbon.

^c Use 6% OC for a "light" value of 2, and 7% OC for a "dark" value of 2.

^d Use 4% OC for a "light" value of 3, and 5% OC for a "dark" value of 3.

To determine mass of carbon per hectare, organic carbon, topsoil depth and bulk density are combined using the equation:

$$[\text{Tonnes OC/ha} = \text{OC\%} \times \text{depth(m)} \times \text{bulk density T/m}^3 \times 10\,000 \text{ m}^2/\text{ha}]$$

Bulk density numerical values are the same whether expressed as g/cm^3 , Mg/m^3 , or T/m^3 . To determine bulk density either take measurements, refer to Table 18, or, as a guide use the bulk density - texture relationships shown in Figure 6, for cultivated topsoils. Figure 6 relates topsoil organic carbon mass per hectare and points deducted.

As an alternative to calculating organic carbon mass, the user may determine the point deductions from Figures 5 and 6. First, determine dry soil colour and depth, either matching or interpolating values: read corresponding mass of carbon in T/ha , from Figure 5. Use this number and select appropriate bulk density (based on texture) in Figure 6 to determine the point deduction. For example, consider a cultivated topsoil (Ap) that is sandy loam, 20 cm deep, and has a dry colour of 10 YR 5/2 (value = 5). Figure 5 and Table 9 indicate that a value of 5 is equivalent to 2 % OC, and with a 20 cm depth, the OC mass per hectare is 40 tonnes. Next, using Figure 6, select the appropriate "line" (estimated bulk density 1.35 T/m^3 based on sandy loam texture) to relate OC T/ha (40) to points deducted (15).

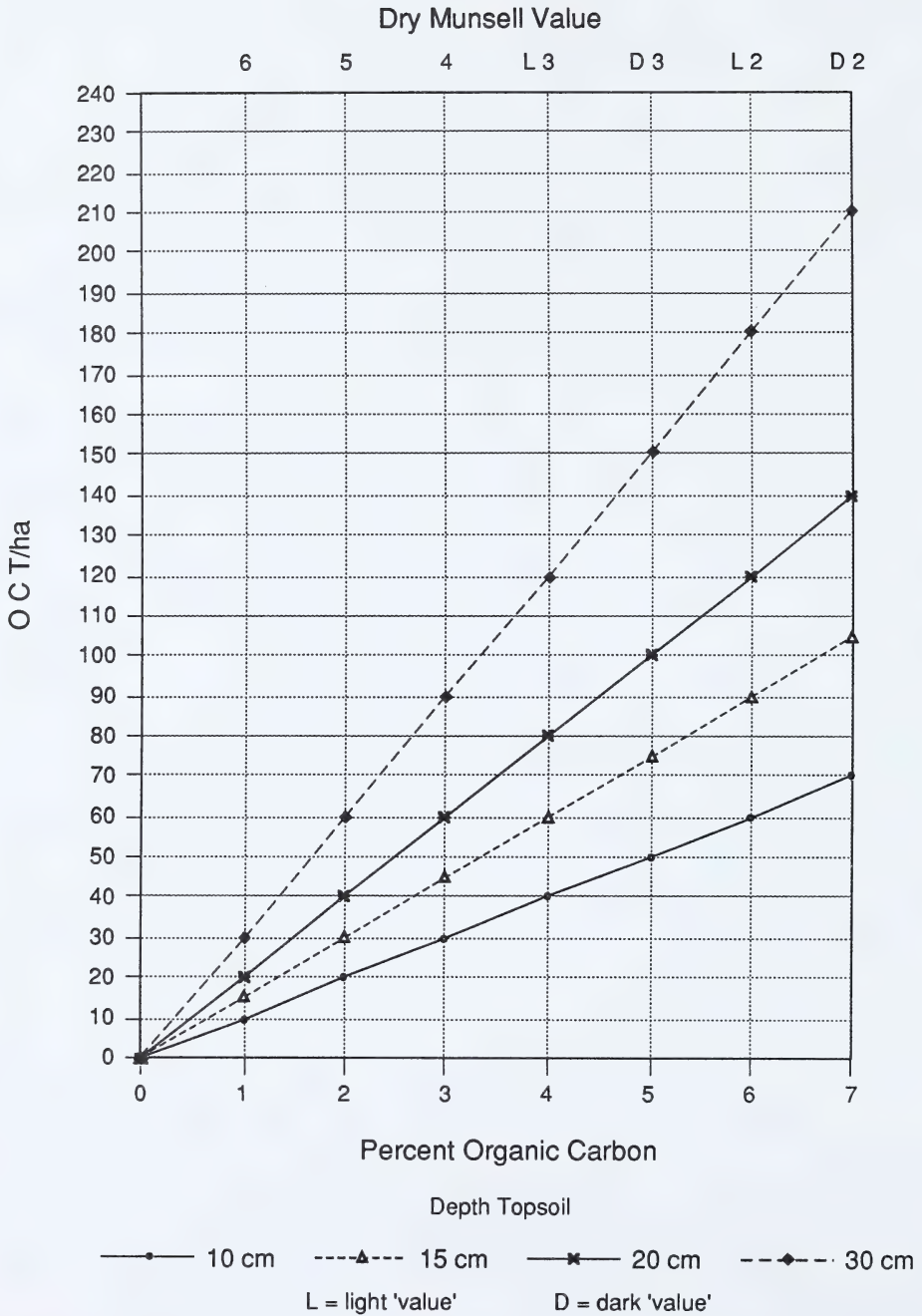


Figure 5. Organic carbon in T/ha based on dry colour and depth.

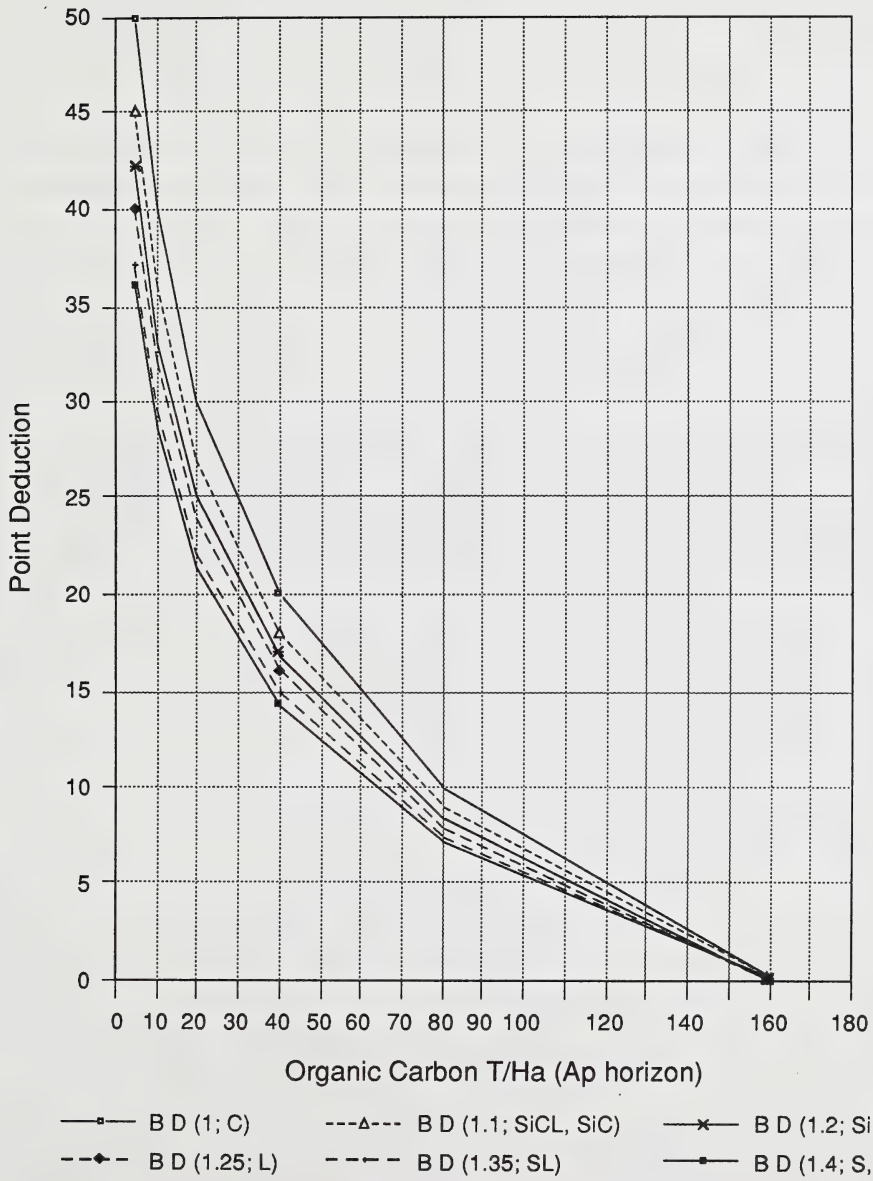


Figure 6. Topsoil organic carbon content and point deduction.

4.1.4 Soil Reaction: Subclass V

A neutral to slightly acid condition is the ideal situation for a balanced nutrient supply. Soil reaction deviating from neutral lowers crop yields so point deductions are made accordingly (Table 10). Soils more acidic than pH 5.0 cause lower yields. At pH levels below 4.0 some elements may be present in toxic quantities. Crops vary in response to acidity with oats the most tolerant and wheat the least of the grains. A pH of 5.5 or less will stunt alfalfa growth.

High pH or alkaline conditions also affect plant response but they are usually associated with saline or sodic conditions (see Sections 4.1.6 and 4.1.7 for discussions of salinity and sodicity). Values above 8.5 only occur if there is a relatively high sodium content associated with a low lime content, a situation rare in Alberta. Where a deduction is made for salinity or sodicity no deduction is made for high pH values (to avoid a double penalty). Seasonal variation in soil pH is in the order of 0.5 units.

Table 10. Point deduction for surface soil pH.

Soil pH ^a	Points deducted
9.0 ^b	60
8.5	20
8.0	5
6.5-7.5	0
6.0	2
5.5	5
5.0	15
4.5	30
4.0	55
3.5	80

^a Measured in saturated paste. Add 0.5 units to pH values measured in CaCl₂.

^b Round off to nearest 0.5 units.

4.1.5 Salinity: Subclass N

Salinity refers to the presence of excessive amounts of soluble salts such as magnesium and sodium sulphates. Salinity affects crop growth through chemical effects of salts as well as reduction of water availability to plants.

Salinity is expressed in terms of electrical conductivity (EC) and is measured in the field or laboratory. It can be estimated from soil and vegetation characteristics. Crops vary appreciably in salt tolerance, with barley generally more tolerant than others. Effects become noticeable at an EC of about 4 dS/m and moderate to severe by an EC of 8 dS/m. There is very little crop growth at an EC of 16 dS/m (see Table 11 and Figure 7).

Table 11. Relationship between surface soil salinity, vegetation response and point deductions.

Salinity ^a EC (dS/m)	Common features	Points ^b deducted
2 ^b	- no apparent signs - affects sensitive crops	0
4	- presence of foxtail - some white specks on soil surface - crop growth affected to some extent	20
8	- plants restricted to salt tolerant species (e.g., Kochia) - white salt crusts common - crops strongly affected	50
16	- plants restricted to species such as red samphire - salt crust and salts throughout profile - little or no crop growth	90

^a Measured in saturated paste.

^b Use Figure 7 to determine intermediate deductions.

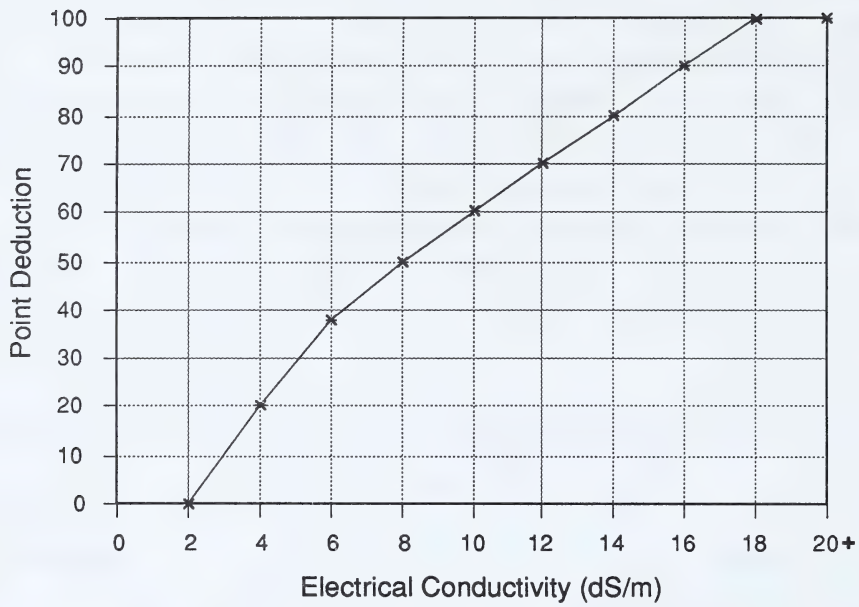


Figure 7. Relationship between point deduction and electrical conductivity for topsoil.

4.1.6 Sodicity and Saturation Percentage: Subclass Y

As the sodium adsorption ratio (SAR) increases above 12 (usually associated with a pH over 8.5), the stability of soil aggregates decreases markedly. The finer soil particles, clays and organic matter, become dispersed resulting in adverse physical conditions (i.e. massive and sticky when wet and extremely hard when dry). Soil colour is darkened by the organic staining.

Saturation percentage (Sat%) is closely associated with SAR in soils of loam or finer texture. In the evaluation of sodicity and saturation percentage only the most limiting of the two measurements is used (Figure 8). High saturation percentages may occur in non-sodic (SAR 4 or less) soils with high organic matter content, if so, do not deduct points for "sodicity". Also, if topsoil texture is coarser than loam, do not deduct SAR.

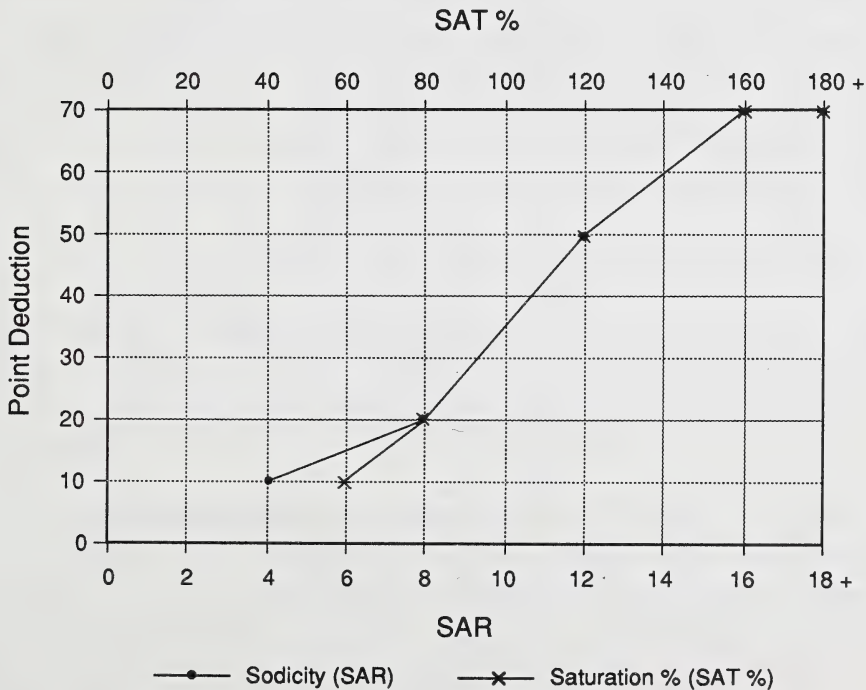


Figure 8. Point deduction for topsoil sodicity and saturation percentage.

4.1.7 Nutrient Imbalance: Subclass K

Free lime (CaCO_3) has effects similar to salt in that it inhibits the availability of water to plants and it may also affect the availability of some nutrients, especially phosphorous. Lime is separated from other salts because it is less soluble, seasonally less variable and less dramatic in its effect on plant growth. It can be measured in the laboratory or estimated from reaction with dilute acid. Deductions for calcareousness are illustrated in Figure 9. A lime amendment of 25 tonnes/ha = about 1% CaCO_3 in the top 20 cm.

If nutrient imbalances, toxicities or deficiencies are known and they require special and greater ongoing inputs, then appropriate deductions should be determined and included in this section, instead of calcareousness. For example, coal enriched sapolite has no physical or chemical soil limitations but it has a high fertilizer requirement, necessitating above normal soil fertilization rates. Peats may need lime or micronutrient applications. Nutrient imbalance limitations can usually be overcome with more intensive management and greater inputs.

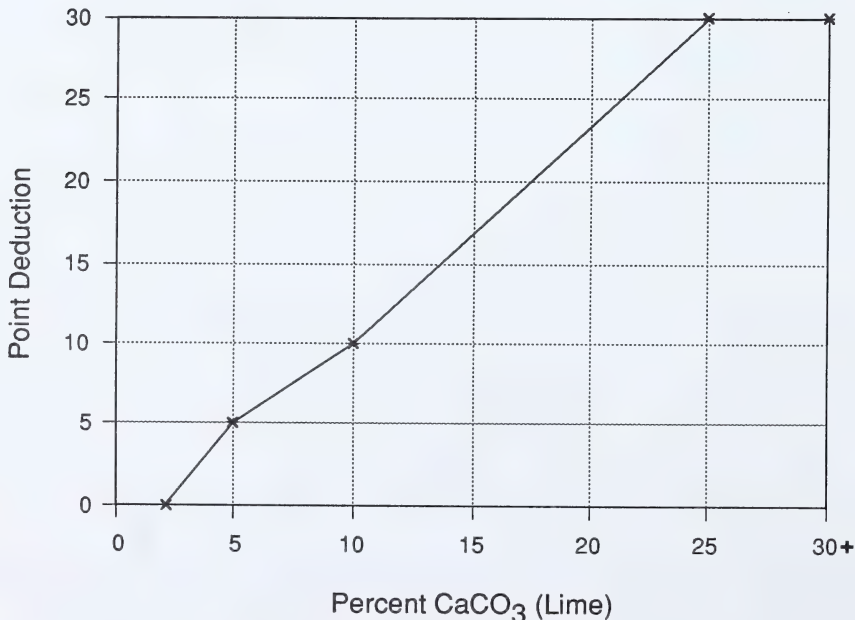


Figure 9. Point deduction for surface calcareousness.

4.1.8 Organic (Peaty) Surface: Subclass O

Organic surfaces, when cultivated, present special management problems related to the degree of decomposition of the peat and depth of organic material. Well decomposed (dark coloured, mesic to humic, sedge) peats, well compacted with a granular structure are the most favourable. Least favourable are the raw (light coloured, fibric, moss) peats which are porous.

Peaty (surface peat) mineral soils grade to Organic soils (deep peat) when the depth of humic or mesic peat exceeds 40 cm (>60 cm if fibric peat). Depths may be difficult to measure when cultivation results in an immediate compaction of the deposit. Mesic peats will compact about 30% and fibric peats about 40%. Within this context the ratings in Table 12 apply.

Table 12. Point deduction for organic (peaty) surfaces.

Depth of Peat (cm) ^a		Degree of decomposition	General structure	General consistence	Points deducted
non-compact	compact				
10	10	humic			0
15	15	humic	compact	friable	5
20	15	mesic			5
25	15	fibric	spongy	fibrous	10
30	30	humic	compact	friable	10
40	30	mesic			15
50	30	fibric	spongy	fibrous	20

^a Depths of <10 cm should be handled as mineral soils.
NOTE: When rating a peaty surface the above ratings address physical handling or cultivation of the peat. Ratings for pH may differ from equivalent pH in mineral soils, nutrient deficiencies may occur, etc. Deductions for the latter should be documented and made under nutrient imbalance.

4.1.9 Topsoil Loss: Subclass G

During the grading process, either when stripping or replacing topsoils, there may be a significant loss of topsoil caused by insufficient removal, loss during storage, uneven replacement, mixing with subsoil, or other reasons. A 5 point deduction is made for every 10 percent loss in thickness of topsoil, based on average control depth or a specified depth.

4.2 SUBSURFACE FACTORS

Subsoil is divided into upper (below topsoil to 50 cm) and lower subsoil (50 to 100 cm). A relative weighting of 2:1 or 67:33% is assigned to these layers, respectively, in calculating the deductions for subsoils. Minimum thickness of upper subsoil to be considered is 15 cm. This will not occur where the topsoil is more than 35 cm thick. If upper subsoil is absent, rate only lower subsoil. The rating of subsoils is adjusted as follows:

1. upper layer deductions $\underline{X} \times 0.67 = \underline{\text{adjusted rating}}$
where X = deduction for upper subsoil layer
2. lower layer deductions $\underline{Y} \times 0.33 = \underline{\text{adjusted rating}}$
where Y = deduction for lower subsoil layer

Subsurface factors are modifiers to the surface rating and are managed as percentage reductions of the primary rating. A depth of 100 cm matches that used for rating undisturbed soils and is considered to be the effective rooting zone for most moderately deep rooted annual crops. Four factors are recognized in this category for both upper and lower subsoils. They are structure, acidity, salinity and sodicity.

4.2.1 Subsoil Structure: Subclass D

Structure and related properties affect root penetration and the availability of water, air and nutrients to the plant. The ratings are subjective, based mainly on the abundance and size of reasonably stable soil aggregates and consistence (Table 13). Perviousness, compaction and rooting also aid in rating subsoil structure.

Table 13. Percent deduction for subsoil structure and consistence.

Structure	Perviousness	Compaction	Rooting	Percent Deduction
Dominant soil aggregates <2 cm diameter, very friable/soft or friable/slightly hard.				
crumb, fine, medium subangular blocky.	moderate, many continuous cracks, pores	none, slight	normal, non-limiting	0
This category equivalent to/includes mellow, AB, Bm, Btj, and some Bt, BC and C horizons. If subsoil does not meet above criteria, proceed to category below, and so forth.				
Dominant soil aggregates <2 cm in diameter, firm/hard.				
medium angular & subangular- blocky.	moderate, common continuous cracks, pores	moderate	slightly restricted	10
This category is equivalent to/includes many Bt, Btnj, Bm(clay) horizons.				
Dominant soil aggregates 2 to 10 cm in diameter, firm/hard.				
coarse, very coarse subangular- blocky & angular blocky, medium prismatic	moderate, common continuous cracks, pores	moderate- severe	moderately restricted	20
This category is equivalent to/includes many Bt, Btnj horizons.				
Dominant soil aggregates 2 to 10 cm in diameter, very firm/very hard.				
cloddy, prismatic, columnar.	slow, few cracks,pores	severe	restricted root mats, compressed roots, along cracks/peds	30
This category is equivalent to/includes many Bnt, Bn, C horizons.				

Continued...

Table 13. Concluded.

Structure	Perviousness	Compaction	Rooting	Percent Deduction
Sands, gravels, outwash deposits, loose materials.				
single grain massive	rapid, many cracks	none	variable restricted due to dryness	30
Dominant soil aggregates 10 to 30 cm diameter, very firm/very hard.				
cloddy, columnar, massive.	very slow, very few cracks, pores	severe-extreme	roots along cracks only	50
This category is equivalent to/includes some Bnt, many C horizons.				
Soil is massive, aggregates >30 cm diameter, extremely firm/extremely hard.				
massive, bedded.	very slow, very few cracks, pores	extreme	no roots, root mat above restricting layer	70
This category results from compaction as in roads, heavy traffic areas, and includes soft bedrock deposits. This material can be augered with difficulty.				
Consolidated material that is massive, >30 cm sized blocks, extremely firm/extremely hard.				
cemented, bedrock, nonsoil.	impervious, no cracks, no pores	extreme	no roots, root mat above restricting layer	90
This category includes hard bedrock deposits, concrete, pavement etc. This material cannot be augered.				

Notes:

For layered, bedded materials, or compacted materials that have firmer/harder consistence, rate the most limiting part of a layer. Rate the most limiting structure or consistence.

Perviousness, compaction and rooting provide supporting evidence to rate the conditions. Perviousness is the capacity of the soil to transmit air and water.

Aggregation is determined by dropping a mass of soil (spade full) one metre onto a hard surface (plywood), and visually estimating the dominant size category of aggregates or soil clods.

4.2.2 Subsoil Reaction: Subclass V

Subsoil pH levels have the same effects on nutrient availability and plant growth as in the surface layer. Alkaline reactions are a problem only if associated with salinity and sodicity dealt with in 4.2.3 and 4.2.4. This section addresses only acid reactions. The impact of specific pH levels is less severe than in the surface layer (Table 14).

Table 14. Percent deduction for subsoil acidity.

Subsoil pH ^a	Percent deduction
≥ 6.0	0
5.5	2
5.0	5
4.5	15
4.0	30
3.5	55

^a Measured in saturated paste. Add 0.5 unit to pH values measured in CaCl₂.
Round off pH to nearest 0.5 units.

4.2.3 Subsoil Salinity: Subclass N

A subsoil salinity deduction is made regardless of the surface or topsoil condition. Deductions are identical to those for topsoil salinity, and are repeated here (Figure 10).

4.2.4 Subsoil Sodidity and Saturation Percentage: Subclass Y

Only the most limiting of SAR or Sat% is deducted. Figure 11 indicates the percent deductions for the various SAR and Sat% classes. If soil texture is coarser than loam, an SAR deduction is not made.

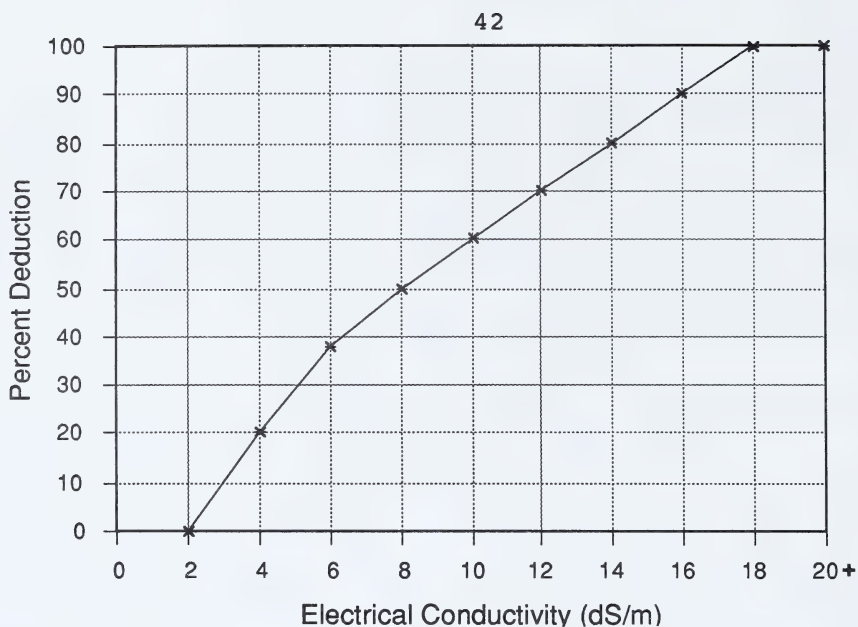


Figure 10. Relationship between percent deduction and electrical conductivity for subsoil.

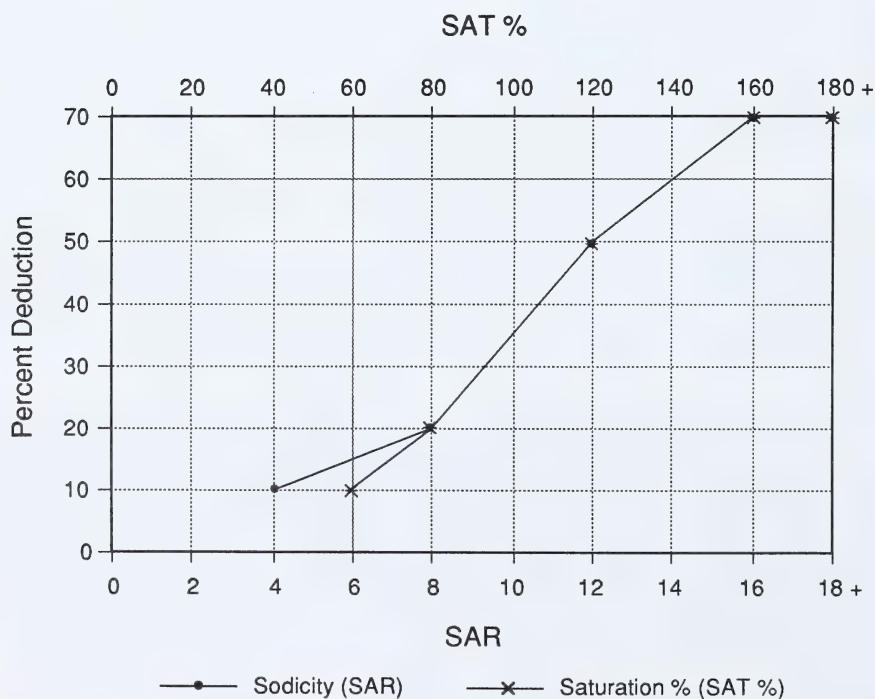


Figure 11. Percent deduction for subsoil sodicity and saturation percentage.

4.3 MOISTURE REGIME: SUBCLASS W

Moisture regime in this context refers to soil-specific evaluations reflecting water supply to the root zone, either excess or deficiency. In evaluation of excessive wetness, the main factor considered is the uppermost level of the water table for a minimum of one month during the growing season. It is not always practical to make physical measurements needed for water table characteristics. There are soil and vegetation features which can be used (Table 15). Where wetness is not a limitation, as in moderately well to very rapidly drained soils, an adjustment is based on climate (P-PE Index - Table 16, and Figure 12). Therefore, as climatic droughtiness increases the soil rating decreases. Apply only one adjustment (use the smaller percentage as the multiplier), either excessive wetness or climatic droughtiness factor. Soil moisture regime is considered a modifier to the entire soil rating and is therefore applied as a percentage multiplier.

Drainage factors should be assessed for present conditions. Soil features respond slowly to changes in the moisture regime complicating the assessment of this factor. For example, drained soils may maintain gley features for many years or newly constructed soils may take time to develop gley features. In such cases the rating should be based on any continuing limitation and not on soil morphology.

Table 15. Soil adjustment factor for excessive wetness.

Wetness Category	Water table depth (cm) (min of 1 mo.)	Common drainage class	Soil/vegetation	Adjustment Factor (%)
W0	> 2 m	moderately well to rapid	normal	100
W1	1-2 m	moderately well	can cultivate 9 out of 10 years	90
W2	< 1 m	imperfectly	can cultivate 8 out of 10 years	80
W3	< 1 m	imperfectly	can cultivate 7 out of 10 years	70
W4	< 1 m	imperfectly	can cultivate 6 out of 10 years	60
W5	< 1 m	imperfectly	gleyed soil can cultivate 5 out of 10 years	50
W6	<50 cm	poorly	gleysolic soils sedges, willows; can cultivate < 5 out of 10 years	30
W7	surface for 1, 2, 3 months	very poorly	gleysolic soils sedges, slough	15
W8	surface for 4 months	very poorly	ponded water	0

Table 16. Soil moisture adjustment factor for climate.

Climate (A) P-PE Index	Adjustment Factor (%)
-250	100
-300	95
-350	90
-400	85
-450	80
-500	75
-550	70
-600	65

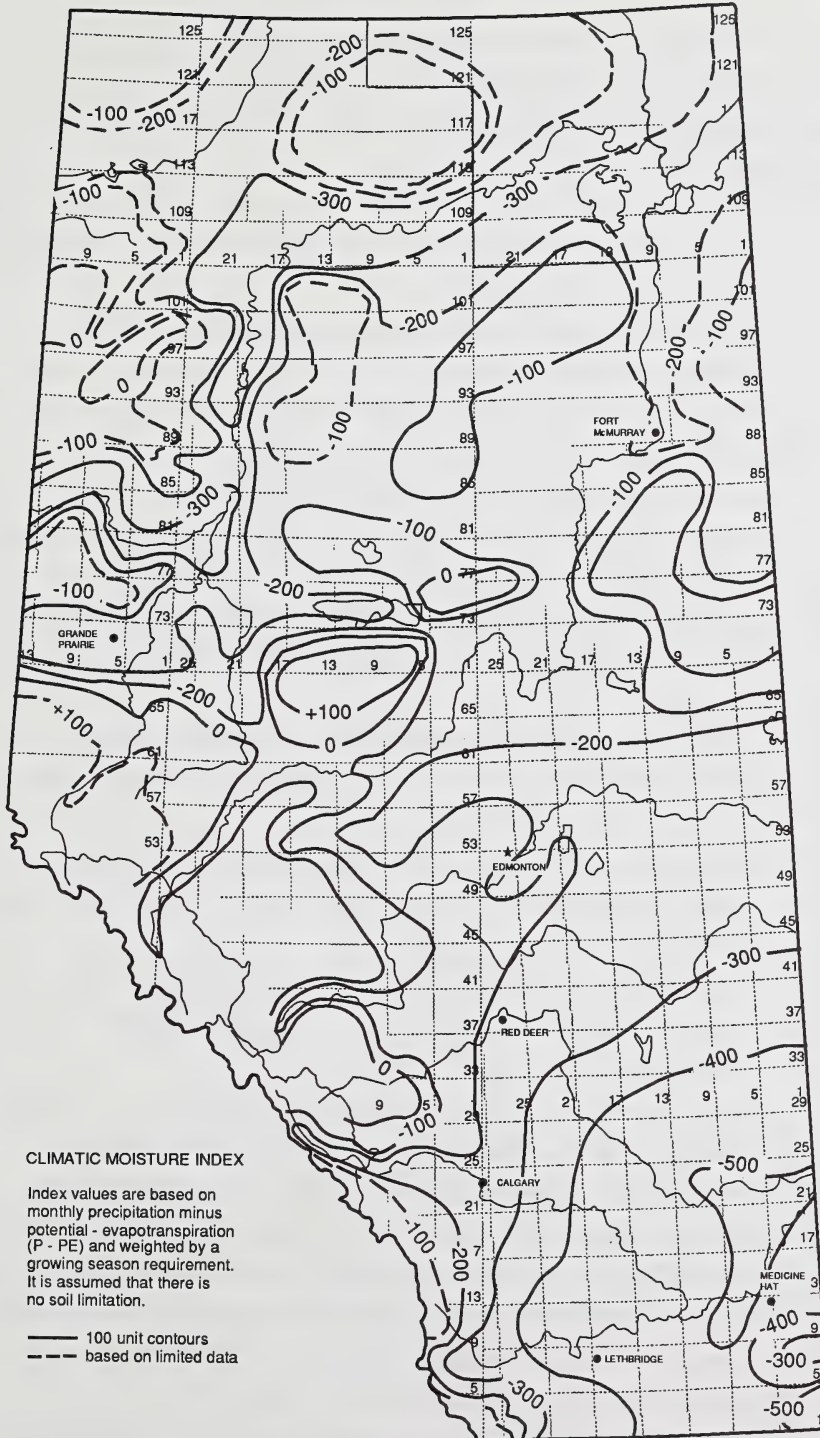


Figure 12. Map of climatic moisture index.

4.4 CALCULATION OF THE MINERAL SOIL RATING (S)

The first page, mineral soil section, of the Agricultural Reclamation Capability Rating Form (Figure 15) is used as follows:

1. Examine surface soil (or supplied information) and fill in a "value" for each parameter. Determine moisture availability based on texture of the upper 100 cm (Table 7) and determine correct moisture deduction. Using the tables/charts in this section assign deductions to other factors. Note that only the most limiting of structure, acidity, salinity, sodicity/sat% is deducted. If peaty, also deduct the most limiting of structure, acidity, salinity or sodicity. Where there is a topsoil loss, compared to a control or specified depth, deduct 5 points per 10% loss in topsoil depth.
2. Total the point deductions for the surface factors and subtract from 100 to give the basic soil rating (a).
3. Determine "values" for the subsoil factors for each subsoil horizon/layer, and deduct the most limiting only.
4. Calculate weighted subsoil percentage deductions.
5. Basic soil rating - subsoil deductions = interim soil rating (d).
6. Determine moisture regime adjustment, multiply by interim soil rating to get final soil rating.
7. Place into a soil capability class using the classification (Table 1). Identify factors which resulted in a greater than 15 point or percentage deduction and assign the appropriate subclass symbol. For example, a 30 point organic carbon deduction and a 20 percent soil structure deduction results in a rating of 50, Class 3FD.

5. THE LANDSCAPE FACTORS

Landscape evaluation relates to management rather than productivity. Because these features can limit commercial agriculture they are rated separately from soil and climate parameters. Topography determines the basic rating while stoniness, landscape pattern and visible erosion are modifiers.

5.1 SLOPE STEEPNESS AND LENGTH (SUBCLASS T)

Slopes above 10% create increasing machinery limitations and erosion hazard. For a sustainable land base it is necessary to manage steep slopes differently from level areas so that erosion does not reduce soil depth and yields. Length and steepness of slope (LS factor) are the controlling landscape parameters and are combined (Figure 13) into a single factor. The relationship among terrain type, surface expression and slope length as conventionally mapped is as follows:

Terrain type	Surface expression	Slope length
simple	undulating level apron fan inclined rolling	>100 m
complex	undulating hummocky ridged	<100 m

5.2 STONINESS FACTOR: SUBCLASS P

Stones/rocks (≥ 10 cm) or gravels (< 10 cm) affect farm management and can lower capability to a non-arable class. Stoniness is rated as a percent deduction. The rating is based on number of stones per 10 x 10 m square to be picked (Figure 14). Deductions for stoniness classes are: S0 - 0%; S1 - 5%; S2 - 20%; S3 - 40%; S4 - 60%; and S5 - 80%. Deduction for gravel is related to volume: % gravel = % deduction (nearest 10%).

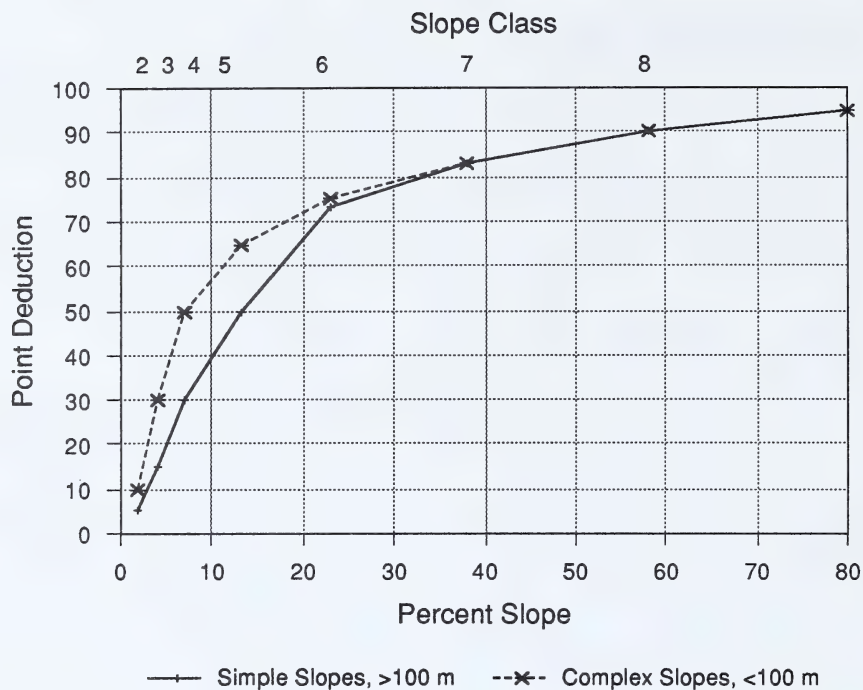


Figure 13. Deduction related to slope steepness and length.

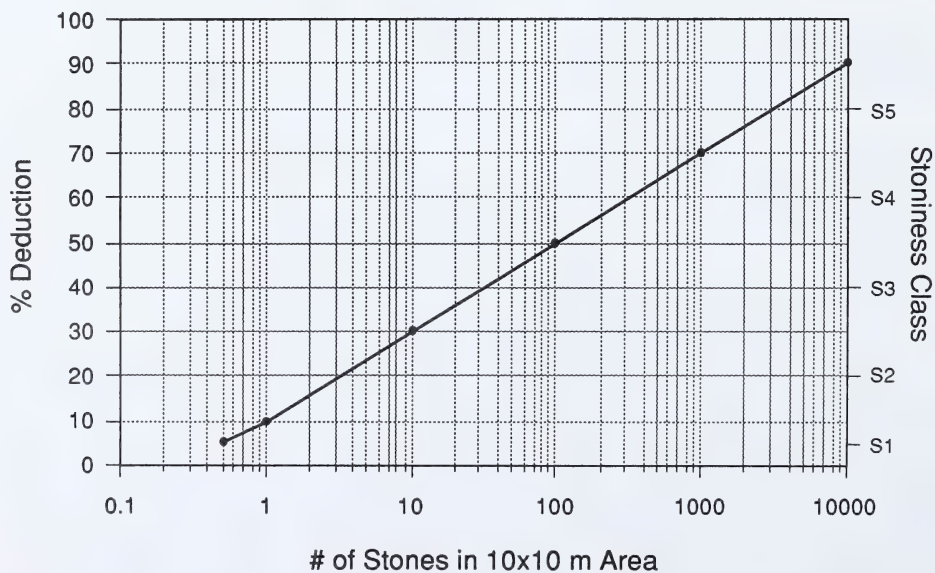


Figure 14. Percent deduction for surface stoniness.

5.3 LANDSCAPE PATTERN (OBSTACLES, FIELD SIZE): SUBCLASS J

Obstacles which operators of large farm machinery must go around (such as sloughs, wellsites, powerpoles, etc.) result in an overlap of field operations and increased input per unit area. The suggested rating is a 1% deduction for every obstacle, to a maximum of 20% per quarter section, assigned to the map unit within which the obstacles occur. For field size: deduct 20% if field is <16 ha (<40 acres) plus an additional 0.25% per obstacle, or 1% if adjusted to a field size of one quarter. A deduction is not made after an obstacle is removed or reclaimed.

5.4 EROSION FACTOR: SUBCLASS E

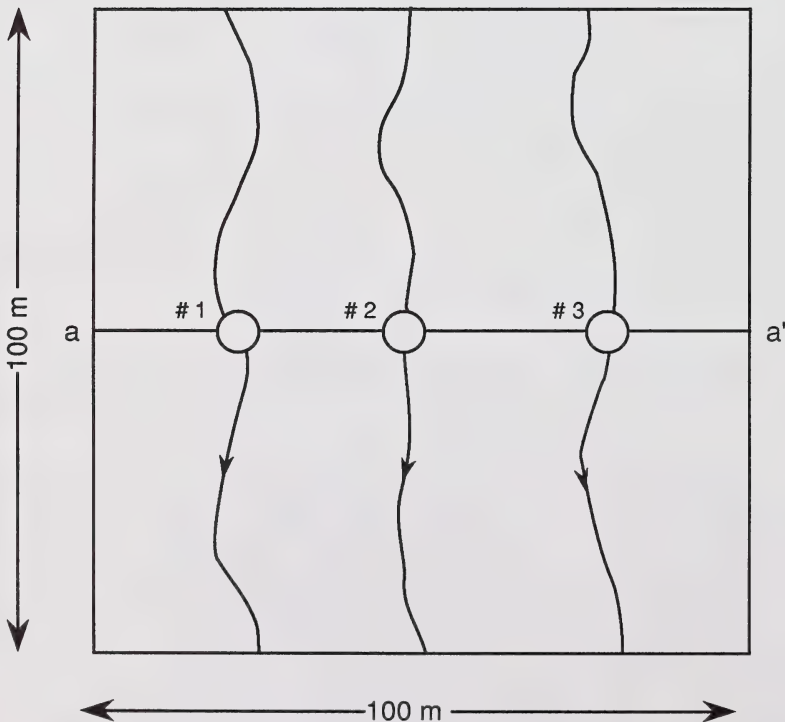
Erosion depends on length and steepness of slope, as well as timing, amount and intensity of precipitation, cropping practices, and kind and condition of soil. The erosion ratings in Table 17 refer to actual visible rill and gully erosion. Only if there are rills or gullies, determine the number of years since reclamation, estimate volume of soil loss by rill and gully erosion (see next page), calculate average annual loss and assign the appropriate deduction. Potential erosion is covered under slope steepness and length.

Table 17. Soil erosion categories.

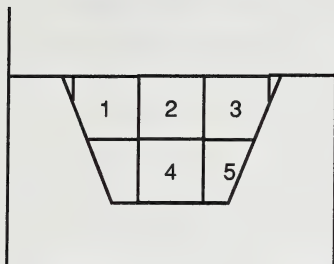
Percent Deduction	Category	-----Annual Soil Loss-----	
		(weight)	(volume)
0	None	< 6 tonnes/ha	<4.4 m ³
10	Slight	6 - <11 tonnes/ha	4.4 - <8 m ³
20	Moderate	11 - <22 tonnes/ha	8 - <16 m ³
30	Severe	22 - <33 tonnes/ha	16 - <24 m ³
40	Very Severe	33 - <55 tonnes/ha	24 - <40 m ³
50	Extreme	≥ 55 tonnes/ha	≥ 40 m ³

Note: Assume average bulk density of 1.35 g/cm³.

To estimate rill and gully erosion loss, select a representative 100 x 100 m square (1 ha) on a slope; establish a transect (a-a') across the middle of the "hectare", along the contour (perpendicular to direction of rills and gullies); tally number of rills/gullies and cross-sectional area of each in decimetres (that is, estimated number of 10 x 10 cm "frames" per cross-section of rill/gully); total number of these "frames" equals soil loss in cubic metres per ha, assuming 100 m length of rills/gullies (see diagram below). For instance, example #1, a rill 20 cm wide at the top, 20 cm wide at the bottom, and 20 cm deep has an approximate cross sectional area of 4 "frames", each 10 x 10 cm. Such a rill that is 100 m long represents a soil loss of 4 m³. If six such rills formed in one year the annual soil loss would be 24 m³/ha, which is a 40% deduction.

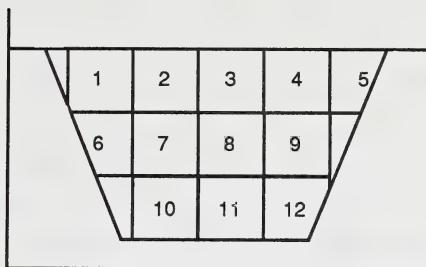


Example #2



Approx. 5 "frames"
 10 cm x 10 cm
 @ 100 m length = 5 m³/ha

Example #3



Approx. 12 "frames"
 10 cm x 10 cm
 @ 100 m length = 12 m³/ha

5.5 CALCULATION OF THE LANDSCAPE RATING (L)

Use page the second page, landscape section, of the Agricultural Reclamation Capability Rating Form (Figure 15) and:

1. Determine the average slope steepness and length, and point deduction.
2. Subtract the deduction from 100 to give the basic landscape rating (a).
3. Assign and record the stoniness/gravel percent deduction.
4. Determine the number obstacles per 1/4 section.
5. At 1% per obstacle, determine the pattern deduction. If field <16 ha, deduct extra 20%.
6. Determine erosion category and assign deduction.
7. Calculate the final landscape rating.
8. Place the landscape factor into a capability class. Identify factors which resulted in a greater than 15 point or percentage deduction and assign the appropriate subclass symbol. For example, a final rating of 75 with 20 points deducted for slope (topography) is rated 2T.

6. THE CLIMATE FACTORS

In rating reclaimed lands the climatic rating is optional. Information required to determine moisture and energy indexes for Alberta are appended (Section 9.2).

7. HOW TO USE THE SYSTEM

This section illustrates the field application of the rating system. It includes:

1. Agricultural Reclamation Capability Rating Form (Figure 15),
2. Soil Description Form (Figure 16).
3. Three examples of complete ratings.

7.1 AGRICULTURAL RECLAMATION CAPABILITY RATING FORM

The rating form documents data relating to the soil, landscape, and climate components and the final rating calculation. Parts of the calculation requiring attention are:

1. In topsoil, only the most limiting of structure (D), pH (V), salinity (N), sodicity (Y), and calcareousness (K) are used in the final deductions. These factors are related and use of all five would result in excessive penalties. Where there is a peaty surface (O), also deduct the most limiting of these five.
2. In upper and lower subsoil deduct the most limiting condition for each layer/horizon. If two parameters are equally limiting they may be listed as subclasses (only if deduction >15).
3. Only one of the climatic A factor and the soil M factor should be shown in the final overall rating even if both are important. When an evaluation of the soil water holding capacity results in a greater than 15 point deduction then use M.
4. Refer to Appendix Section 9.2 to complete the climatic rating.

MINERAL SOIL (S)

Location: _____	Surveyor: _____	Date: _____	
-----------------	-----------------	-------------	--

1. <u>Surface Factors</u>	<u>value</u>	<u>point deduction</u>
- AWHC to 100 cm (M)	_____	_____
- structure/ consistence (D)*	_____	_____
- organic carbon %	_____	_____
and depth (F)	_____	_____
- acidity (V)*	_____	_____
- salinity (N)*	_____	_____
- sodicity/saturation % (Y)*	_____	_____
- nutrient imbalance (K)*	_____	_____
- peaty surface (O)**	_____	_____
- topsoil loss (G)	_____	_____
* (deduct most limiting D, V, N, Y or K)		
** (when deducting O, also deduct *)		
Basic Soil Rating =	100 -	_____ = (a)

2. <u>Upper Subsoil Factors</u>	<u>% deduction</u>
- structure (D)*	_____
- acidity (V)*	_____
- salinity (N)*	_____
- sodicity/saturation % (Y)*	_____
* (deduct one only, most limiting)	
Upper subsoil deduction =	_____ % of (a) x 0.67 = (b)

3. <u>Lower Subsoil Factors</u>	<u>% deduction</u>
- structure (D)*	_____
- acidity (V)*	_____
- salinity (N)*	_____
- sodicity/saturation % (Y)*	_____
* (deduct one only, most limiting)	
Lower subsoil deduction =	_____ % of (a) x 0.33 = (c)

Interim Soil Rating = (a)	_____	- (b)	_____	- (c)	_____	= (d)	_____
---------------------------	-------	-------	-------	-------	-------	-------	-------

4. <u>Moisture Regime Factor (W)</u>	<u>Adjustment</u>
- wetness*	_____
- climatic factor*	_____
* (deduct one only, smaller percentage)	
Moisture Regime Adjustment = (W)	(e) = _____

FINAL SOIL RATING (S) = (d)	_____	x (e)	_____	=	_____
=Class	_____	,	_____	subclasses	_____

Figure 15. Agriculture reclamation capability rating form. Continued.

LANDSCAPE (L)

	<u>value</u>	<u>point deduction</u>
1. <u>Slope (T)</u>		
- slope steepness	<u>%</u>	
- slope length	<u>m</u>	
Basic landscape rating = 100 -		<u> </u> = (a) <u> </u>
2. <u>Stoniness (P)</u>		<u>% deduction</u>
- class		
Stoniness deduction =	<u> </u>	<u>%</u> x (a) = (b) <u> </u>
3. <u>Pattern (J)</u>		<u>% deduction</u>
- no. of obstacles per quarter section	<u> </u>	<u> </u>
- field size <16 ha	<u> </u>	<u> </u>
Pattern deduction =	<u> </u>	<u>%</u> x (a) = (c) <u> </u>
4. <u>Erosion (E)</u>		<u>% deduction</u>
- estimated volume soil loss in gullies	<u> </u>	
- years since reclamation	<u> </u>	
- annual gully erosion	<u> </u>	
Erosion deduction =	<u> </u>	<u>%</u> x (a) = (d) <u> </u>
FINAL LANDSCAPE RATING (L) = (a) <u> </u> - (b) <u> </u> - (c) <u> </u> - (d) <u> </u> = <u> </u>		
= Class <u> </u> , <u> </u> subclasses		

Figure 15. Continued...

$$A = 100 -$$

EGDD index

$$H = 100 - \quad =$$

index	factors
-------	---------

or class _____,

or glass

_____ or class _____,

_____ or class _____,

Figure 15. Concluded.

Location/Site												
Map Unit/ Soil Series												
Soil Classification												
Parent Material				Genetic				Expression				
Texture				Topsoil				Subsoil				
Drainage				R	W	MW	I	P	VP			
Wetness Category				W0	W1	W2	W3	W4	W5	W6	W7	W8
Topography				Percent				Length m				
Surface Stoniness				Gravel				Stones				
Pattern				No. obstacles/ 1/4 Field size <16 ha				≥ 16 ha				
Gully and Rill Erosion (visible)				None	Sli	Mod	Sev	V.Sev	Ext			
Land Use (at time of inspection)				Crop	Hay	Nat.Rge	Imp.Rge.	Bush				
Crop/Sod Quality				Good				Fair		Poor		
Compaction				None	Sli	Mod	Sev	V Sev	Ext			
EXAMPLE PROFILE:				Samples								
Horizon	Depth	Colour	Texture	Structure				Consistence				

Comments:

Figure 16. Soil description form.

Location/Site	Paintearth									
Map Unit/ Soil Series	Topsoil/ subsoil (1 m)									
Soil Classification										
Parent Material	Genetic	M	Expression u							
Texture	Topsoil	L	Subsoil	CL						
Drainage	R	<u>W</u>	MW	I	P	VP				
Wetness Category	W0	W1	W2	W3	W4	W5	W6	W7	W8	
Topography	Percent	4		Length m			200			
Surface Stoniness	Gravel			Stones		S1				
Pattern	No. Obstacles/ 1/4 Field size		1/4 ha		1	≥ 16 ha				
Gully and Rill Erosion (visible)	None	Sli	Mod	Sev	V. Sev	Ext				
Land Use	Crop	<u>Hay</u>	Nat. Rge	Imp. Rge.		Bush				
Crop/Sod Quality	<u>Good</u>	Fair		Poor						
Compaction	None	Sli	Mod	<u>Sev</u>	V	Sev	Ext			
EXAMPLE PROFILE:										
Horizon	Depth	Colour	Texture		Structure		Consistence			
TS	0-17	4/2d	L		granular		friable			
US	17-50	4/3a	CL		2-10 cm		hard			
LS	50-100	4/3a	CL		2-10 cm		extr hard			

Comments:

MINERAL SOIL (S)

Location: Paintearth Surveyor: Leskiw Date:

1. Surface Factors	Value	point deduction
- AWHC to 100 cm (M)	167 mm	0
- structure/ consistence (D)*	gran, friable	5
- organic carbon %	4/2d	
- and depth (F)	17 cm	13
- acidity (V)*	7.0	0
- salinity (N)*	1.8	0
- sodicity/saturation % (Y)*	3.7	0
- nutrient imbalance (K)*	-	-
- peaty surface (O)**	-	-
- topsoil loss (G)	-	-
* (deduct most limiting D, V, N, Y or K)		
** (when deducting O, also deduct *)		
Basic Soil Rating =	100 -	18 = (a) 82
2. Upper Subsoil Factors		
- structure (D)*	2-10, hard	20
- acidity (V)*	7.2	0
- salinity (N)*	2.4	8
- sodicity/saturation % (Y)*	2.2	12
* (deduct one only, most limiting)		
Upper subsoil deduction =	20	% of (a) x 0.67 = (b) 11
3. Lower Subsoil Factors		
- structure (D)*	2-10, extr hard	70
- acidity (V)*	7.2	0
- salinity (N)*	2.4	0
- sodicity/saturation % (Y)*	2.2	0
* (deduct one only, most limiting)		
Lower subsoil deduction =	70	% of (a) x 0.33 = (c) 19

Interim Soil Rating = (a) 82 - (b) 11 - (c) 19 = (d) 52				
4. Moisture Regime Factor (W)				
- wetness*	W0	Adjustment		
- climatic factor*	-300	100		
* (deduct one only, smaller percentage)		95		
Moisture Regime Adjustment = (W)		(e) = 95%		
FINAL SOIL RATING (S) = (d) 52 x (e) 0.95 = 49				
=Class 3		D		
		subclasses		

1. Slope (T)

LANDSCAPE (L)

value

point deduction

- slope steepness

4%

- slope length

200 m

Basic landscape rating = 100 -

15

85

2. Stoniness (P)

- class

S1

Stoniness deduction =

5%

x (a) = (b)

4

3. Pattern (J)

- no. of obstacles per quarter section

1

- field size <16 ha

1%

x (a) = (c)

0.8

4. Erosion (E)

- estimated volume soil loss in gullies

-

- years since reclamation

-

- annual gully erosion

-

Erosion deduction =

-

x (a) = (d)

0

FINAL LANDSCAPE RATING (L) = (a) 85 - (b) 4 - (c) 1 - (d) 0 = 80

= Class 1 , subclasses

1. Moisture component (A)

value

point deduction

P-PE index

A = 100 -

-300

2. Energy component (H)

EGDD index

H = 100 -

1300

FINAL CLIMATE RATING = lower of A or H (C) 75

= Class 2 , A H subclass

FINAL RATING CALCULATION

S = 49

index

or class

3

,

D

L = 80

or class

1

,

H

C = 75

or class

2

,

A

Class

S

L

C

Index

Class

3

3

1

2

D

-

A

H

80-100

60-79

45-59

30-44

20-29

10-19

0-9

1

2

3

4

5

6

7

Comments

58

Location/site		Cessford									
Map Unit/ Soil Series		Chin									
Soil Classification		Orthic Brown									
Parent Material		Genetic FL Expression b									
Texture		Topsoil L Subsoil L-CL									
Drainage		R W MW I P VP									
Wetness Category		W0 W1 W2 W3 W4 W5 W6 W7 W8									
Topography		Percent 2% Length m 200									
Surface Stoniness		Gravel - Stones S0									
Pattern		No. obstacles/ 1/4 Field size <16 ha - <u>≥ 16 ha</u>									
Gully and Rill Erosion (visible)		None Sli Mod Sev V.Sev. Ext									
Land Use		Crop Hay Nat.Rge Imp.Rge. Bush									
Crop/Sod Quality		Good Fair Poor									
Compaction		None Sli Mod Sev V Sev Ext									
EXAMPLE PROFILE:											
Horizon	Depth	Colour	Texture	Structure	Consistence						
Ap	0-15	4/4d	L	granular	friable						
Bm	15-50	5/4d	L	wf SBK	sli hard						
Ccas	50-100	5/3m	L-CL	ma, <2 cm	sli hard						

Comments:

MINERAL SOIL (S)

Location: Cessford Surveyor: Leskiw Date:

1. Surface Factors Value point deduction

- AWHC to 100 cm (M) 150 0
- structure/ consistence (D)* gran, friable 5
- organic carbon % 4/4d 14
- and depth (F) 15
- acidity (V)* 6.2 2
- salinity (N)* 0.25 0
- sodicity/saturation % (Y)* 0.5 0
- nutrient imbalance (K)* - -
- peaty surface (O)** - -
- topsoil loss (G) - -
- * (deduct most limiting D, V, N, Y or K)
- ** (when deducting O, also deduct *)

Basic Soil Rating = 100 - 19 = (a) 81

2. Upper Subsoil Factors % deduction

- structure (D)* <2 cm, sli hard 0
- acidity (V)* 6.9 0
- salinity (N)* 1.56 0
- sodicity/saturation % (Y)* 7.8 18
- * (deduct one only, most limiting)

Upper subsoil deduction = 18 % of (a) x 0.67 = (b) 10

3. Lower Subsoil Factors % deduction

- structure (D)* <2 cm, sli hard 0
- acidity (V)* 8.0 0
- salinity (N)* 8.98 55
- sodicity/saturation % (Y)* 10.5/ 58% 40
- * (deduct one only, most limiting)

Lower subsoil deduction = 55 % of (a) x 0.33 = (c) 15

Interim Soil Rating = (a) 81 - (b) 10 - (c) 15 = (d) 56

4. Moisture Regime Factor (W) Adjustment

- wetness* W0 100
- climatic factor* -450 80
- * (deduct one only, smaller percentage)
- Moisture Regime Adjustment = (W) (e) = 80%

FINAL SOIL RATING (S) = (d) 56 x (e) 0.80 = 45

=Class 3, W N subclasses

CLIMATE (C)

1. Moisture component (A)	value	point deduction
P-PE index	-450	
	A = 100 -	45 = 55
2. Energy component (H)		
EGDD index	1400	
	H = 100 -	13 = 87

FINAL CLIMATE RATING = lower of A or H (C) 55

=	Class 3	A
		<u>subclass</u>

FINAL RATING CALCULATION

index		factors	
S = 45	or class 3	W	N
L = 95	or class 1		
C = 55	or class 3	A	

Class	S	L	C	Index	Class
				80-100	1
			subclasses		
3	3	1	3	60-79	2
	W	N	-	45-59	3
				30-44	4
				20-29	5
				10-19	6
				0-9	7

Comments

Location/Site	Near Edmonton									
Map Unit/ Soil Series	Peace Hills									
Soil Classification	Orthic Black Chernozemic									
Parent Material	Genetic	F	Expression	u						
Texture	Topsoil	FSL	Subsoil	FSL						
Drainage	R	W	MW	I	P	VP				
Wetness Category	W0	W1	W2	W3	W4	W5	W6	W7	W8	
Topography	Percent	2-5		Length m		20				
Surface Stoniness	Gravel	-		Stones		S0				
Pattern	No. obstacles/ 1/4 Field size <16 ha 3 ≥ 16 ha									
Gully and Rill Erosion (visible)	None Sli Mod Sev V.Sev Ext									
Land Use	Crop	Hay	Nat.Rge	Imp.Rge.	Bush					
Crop/Sod Quality	Good	Fair		Poor						
Compaction	None	Sli	Mod	Sev	V Sev	Ext				
EXAMPLE PROFILE:										
Horizon	Depth	Colour	Texture	Structure	Consistence					
TS	0-30	3/1d	FSL	wf granular	v friable					
US	30-50	4/3m	FSL	wf SBK	v friable					
LS	50-100	4/3m	FSL	wf SBK	v friable					

Comments:

MINERAL SOIL (S)

Location:	Peace Hills	Surveyor:	Leskiw	Date:		
1. Surface Factors					value	point deduction
-	AMHC to 100 cm (M)		100 mm		17	
-	structure/ consistence (D)*		f gran, v friable		0	
-	organic carbon %		3/1d		5	
	and depth (F)		30 cm		0	
-	acidity (V)*		6.7		0	
-	salinity (N)*		0.4		0	
-	sodicity/saturation % (Y)*		0.3		0	
-	nutrient imbalance (K)*		-		-	
-	peaty surface (O)**		-		-	
-	topsoil loss (G)		-		-	
*	(deduct most limiting D, V, N, Y or K)					
**	(when deducting O, also deduct *)					
	Basic Soil Rating =		100 -		22	= (a) 78
2. Upper Subsoil Factors					% deduction	
-	structure (D)*		f SBK, v friable		0	
-	acidity (V)*		7.4		0	
-	salinity (N)*		0.6		0	
-	sodicity/saturation % (Y)*		0.3		0	
*	(deduct one only, most limiting)					
	Upper subsoil deduction =		0	% of (a) x 0.67	= (b) 0	
3. Lower Subsoil Factors					% deduction	
-	structure (D)*		f SBK, v friable		0	
-	acidity (V)*		7.4		0	
-	salinity (N)*		0.6		0	
-	sodicity/saturation % (Y)*		0.3		0	
*	(deduct one only, most limiting)					
	Lower subsoil deduction =		0	% of (a) x 0.33	= (c) 0	
Interim Soil Rating = (a) 78 - (b) 0 - (c) 0 = (d) 78						
4. Moisture Regime Factor (W)					Adjustment	
-	wetness*		W0		100	
-	climatic factor*		-200		100	
*	(deduct one only, smaller percentage)					
Moisture Regime Adjustment = (W)					(e) = 100%	
FINAL SOIL RATING (S) = (d) 78 x (e) 1.0 = 78						
=Class 2					M	
					subclasses	

1. Slope (I)

LANDSCAPE (L)

value

point deduction

2-5%

10

20 m

10

Basic landscape rating = 100 -

90

2. Stoniness (P)

class

deduction

S0

-

-

x (a) = (b)

0

Stoniness deduction =

0

3. Pattern (J)

no. of obstacles per quarter section

3

field size <16 ha

3%

x (a) = (c)

3

Pattern deduction =

3

4. Erosion (E)

estimated volume soil loss in gullies

-

years since reclamation

-

annual gully erosion

-

Erosion deduction =

0

FINAL LANDSCAPE RATING (L) = (a) 90 - (b) 0 - (c) 3 - (d) 0 = 87

= Class 1

subclasses

CLIMATE (C)

1. Moisture component (A)

value

point deduction

P-PE index

-200

A = 100 -

0

2. Energy component (H)

EADD index

1200

H = 100 -

38

FINAL CLIMATE RATING = lower of A or H (C) 62

=

Class 62

subclass

FINAL RATING CALCULATION

S = 78

index

or class

2

factors

M

L = 87

or class

1

C = 62

or class

2

H

Class

S

L

C

Index

Class

2

subclasses

2

1

2

M

-

H

80-100

60-79

45-59

30-44

20-29

10-19

0-9

1

2

3

4

5

6

7

Comments

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9. APPENDIX

9.1 BULK DENSITY, TEXTURE, STRUCTURE AND CONSISTENCE.

The general relationships between bulk density, texture and root growth suggest that a bulk density of 1.8 g/cm^3 will essentially restrict root growth. Bulk density is not easily measured in the field but there are some general relationships to structure and consistence of undisturbed soils which can be used for estimating resistance to root growth (Table 18). Be aware that these are common, not absolute, relationships.

Table 18. Common relationships between kind of horizon, structure, consistence, texture and bulk density.

Kind of horizon	Common structure	Common consistence dry/moist	-----g/cm ³ -----					
			S LS	SL	L	SiL CL	SiCL SiC	C
Ah	granular	sl. hard friable	1.30	1.20	1.15	1.10	1.00	0.95
Ae	platy, massive	soft, sl. hard friable	1.45	1.40	1.35	1.30	1.30	--
Ap (>1% OM)	granular	friable	1.40	1.35	1.25	1.20	1.10	1.05
Ap (<1% OM)	massive friable-firm	soft-hard	1.40	1.40	1.40	1.35	1.30	1.25
Bm	subangular prismatic	sl. hard friable-firm	1.50	1.45	1.40	1.40	1.35	1.30
Btj	blocky prismatic	hard firm	1.50	1.50	1.45	1.45	1.45	1.40
Bt	blocky	hard-v. hard firm-v. firm	--	1.55	1.55	1.60	1.60	1.50
Btnj	blocky-columnar	v. hard v. firm	--	1.50	1.50	1.50	1.50	1.45
Bnt	columnar-blocky	ex. hard ex. firm	--	1.60	1.60	1.65	1.60	1.50
Bn	columnar-massive	ex. hard ex. firm	--	--	1.65	1.65	1.60	1.50
Bf	wk. granular massive	sl. firm friable	1.50	1.45	1.35	1.35	--	--

Source: ASAC 1987a.

9.2 CLIMATIC EVALUATION

Climate is an integral part of dryland agricultural capability in Alberta so the indices developed reflect a concern for the common crops of the area and the summer growing season. The two principal variables determining climate capability are an energy factor and a moisture factor, the most limiting of which determines the basic climatic rating. In the Land Capability Classification for Arable Agriculture in Alberta (ASAC 1987a), four modifiers; spring moisture, fall moisture, fall frost, and hail, are also recognized as having an effect on the climatic assessment of agricultural capability. These modifiers are omitted in this system because, except for hail risk in the Wetaskiwin-Lacombe-Red Deer area, they have little impact on climatic ratings in the area of arable agriculture. In determining moisture and energy indexes from the maps for specific areas the user should interpolate the value to the nearest 50 units using the closest isolines.

9.2.1 Moisture Component (A)

The moisture component is a simplified moisture balance calculation based on monthly precipitation (P) and potential evapotranspiration (PE) (Baier and Robertson 1965). The monthly balances are weighted in accordance with general crop requirements such that:

$$(P-PE) \text{ index} = 0.5(\text{May}) + 1.5(\text{June}) + 2.0(\text{July}) + 1.0(\text{Aug})$$

The general distribution of the moisture index is shown in Figure 12. The critical points considered in development of the rating (Figure 17), assuming no soil limitation, are:

1. P-PE < -100: No limitation.....= 0 points
2. P-PE @ -300: Is close to the Black/Dark Brown soil zone boundary.
Class 2.....= 25 points
3. P-PE @ -400: Is near the point where one major crop (barley) is nearly excluded from the cropping system. It is close to the Dark Brown/ Brown

soil zone boundary.

Class 3...35 to 40 points

4. P-PE @ -500: Is the driest part of Alberta and is near the bottom of Class 3.....50 points

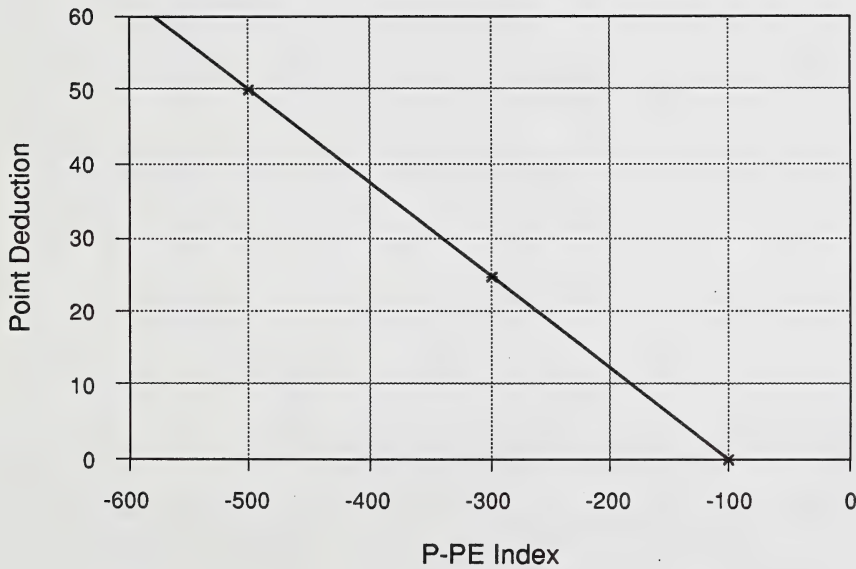


Figure 17. Point deductions for moisture index values.

9.2.2 Energy Component (H)

The energy component is based on an effective growing degree day (EGDD) calculation including length of season, degree days, day length and diurnal temperature range parameters.

The start of a growing season is the first period of five consecutive days with mean temperatures above 5°C after March 15. The end of the growing season is the average date of first frost of 0°C after July 15. This is similar but not identical to frost-free period. The starting date is an approximation of the soil temperature threshold for germination. The number of degree days over 5°C are accumulated over the season described above.

A major adjustment of the GDD value is applied to recognize the effect of the longer day length in the north. The value of the modification varies from 1 at 49° to 1.14 at 60° N latitude. An additional minor (+/-5%) adjustment recognizes daily temperature range.

Point deductions for energy (heat or temperature) are shown in Figure 18, based on the Alberta map, Figure 19. Agro-climatic classes for Alberta are shown in Figure 20.

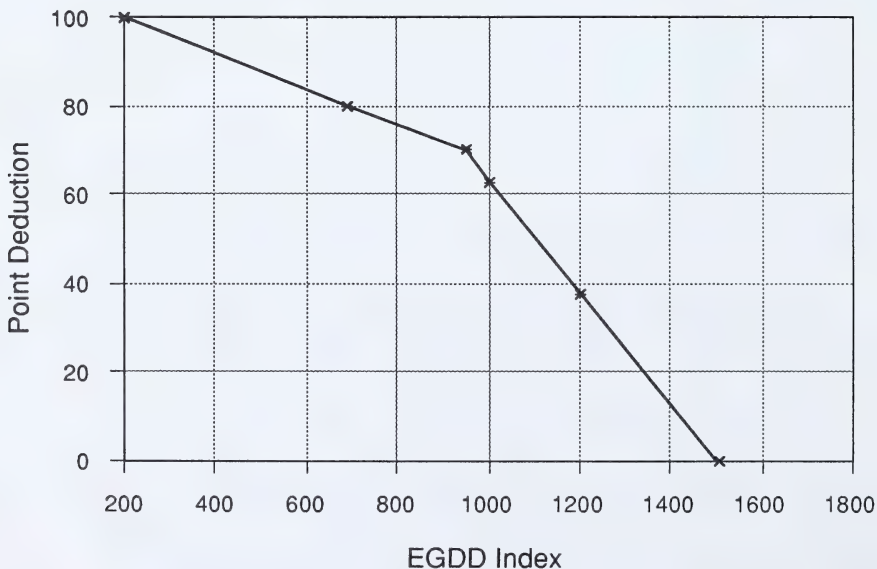


Figure 18. Point deductions for energy index (EGDD) values.

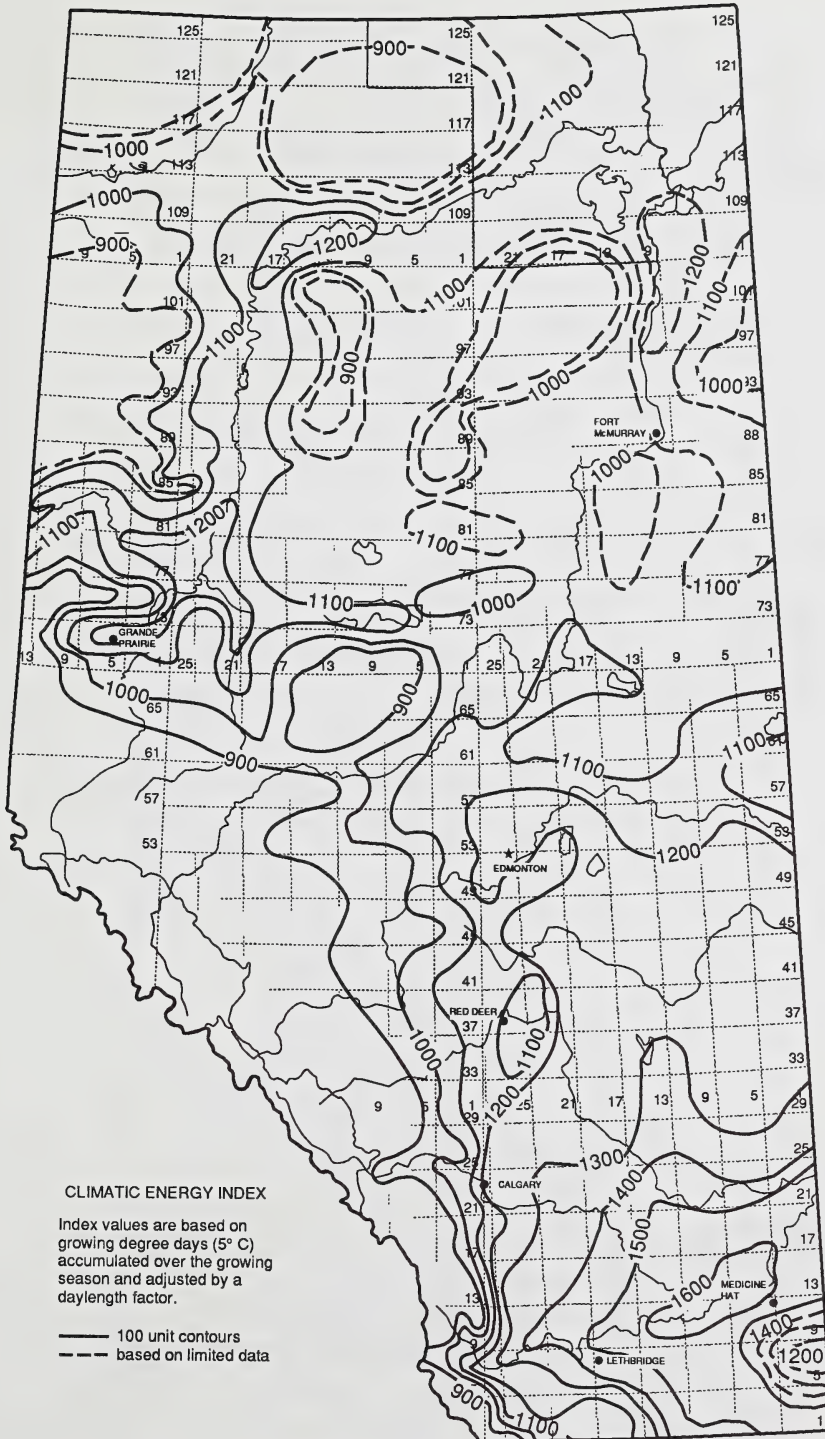


Figure 19. Map of climatic energy index.

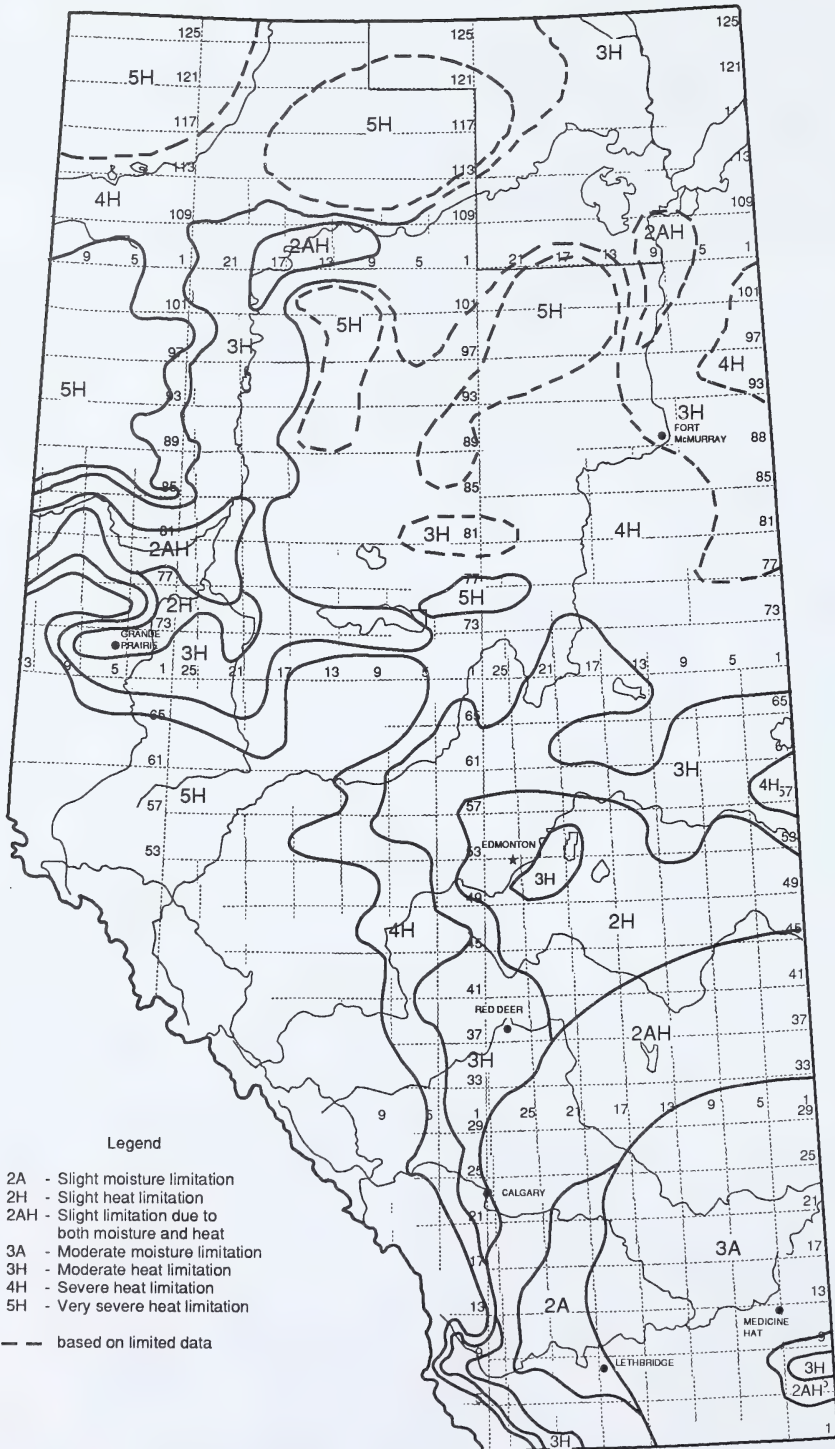


Figure 20. Generalized agroclimatic classes for Alberta.

Critical points used for development of the rating are based on known crop requirements and Alberta farming experience, as follows:

- | | | |
|----|------------|---|
| 1. | 1500 EGDD: | No limitation..= 0 points |
| 2. | 1200 EGDD: | Close to the point where wheat drops to a minor component in a dominantly barley system.
Class 3..... = 40 points |
| 3. | 1100 EGDD: | Near the point where annual crops occupy less than 50% of the cultivated area. This is close to marginal or Class 4.....= 50 points |
| 4. | 950 EGDD: | This marks the edge of arable agriculture. Class 5.....= 70 points |
| 5. | 200 EGDD: | No agricultural potential....= 100 points |

9.3 CALCULATION OF THE CLIMATE RATING

The rating form (Figure 15) facilitates the calculation.

Suggested steps are:

1. Locate the site on the climate moisture map (Figure 12).
2. Estimate the moisture index (interpolate to nearest 50 units between closest isolines) and enter the value on the worksheet.
3. Assign the deduction from Figure 17.
4. Subtract deduction from 100 to determine the A rating.
5. Locate the site on the energy map (Figure 19).
6. Estimate the energy index and enter on the worksheet (interpolate to nearest 50 units).
7. With reference to Figure 18, assign the deduction.
8. Subtract deduction from 100 to determine the H rating.

9. The basic climate rating is the lowest of A or H.
10. Assign a capability class using Table 1.

Identify any factors which resulted in a 15 or greater point deduction and assign the appropriate subclass symbols. For example, a final rating of 55, with a 20 point deduction for moisture and a 25 point deduction for structure would be 3DA.

10. GLOSSARY

- A horizon:** A mineral horizon formed at or near the surface in the zone of removal of materials in solution and suspension, or maximum accumulation of organic carbon, or both.
- Ae:** An horizon that has been eluviated of clay, iron, aluminum, or organic matter, or all of these.
- Ah:** An horizon in which organic matter has accumulated as a result of biological activity.
- Ap:** An horizon markedly disturbed by cultivation or pasture.
- acid soil:** A soil having a pH of less than 7.0.
- aggregate:** Many fine soil particles held together in a single cluster, such as a clod or crumb. Many properties of an aggregate differ from those of an equal mass of unaggregated soil.
- alkaline soils:** Any soil that has a pH greater than 7.0.
- arable:** Tillage; agricultural production based on cultivation practices; land that is cultivated or capable of being cultivated. Arable is used as a comparison to agriculture based on grazing (non-cultivated) systems.
- B horizon:** A subsoil horizon characterized by one of:
- a) an enrichment in clay, iron, aluminum, or humus (Bt or Bf).
 - b) a prismatic or columnar structure that exhibits pronounced coatings or staining associated with significant amounts of exchangeable sodium (Bn or Bnt).
 - c) an alteration by hydrolysis, reduction, or oxidation to give a change in colour or structure from the horizons above or below, or both (Bm).
- bedrock:** The solid rock underlying soils and the regolith or exposed at the surface.
- Brunisolic:** An order of soils whose horizons are developed sufficiently to exclude them from the Regosolic Order but lack the degrees or kinds of horizon development specified for soils in other orders. They always have Bm or Btj horizons.
- bulk density (soil):** The mass of dry soil per unit bulk volume.
- bulk density:** The weight of oven-dry soil per unit bulk volume, including air space. Usually expressed as grams/cubic centimetre.
- C horizon:** A mineral horizon comparatively unaffected by the pedogenic processes operative in the A and B horizons except for the process of gleying (Cg) or the accumulation of calcium carbonate (Cca) or other salts (Csa). A naturally calcareous C horizon is designated Ck.
- calcareous soil:** Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1N hydrochloric acid.
- capability:** Focuses on the nature and degree of limitations imposed by the physical characteristics of a land unit for a certain use.

capability class (soil): The class indicates the general suitability of the soils for agricultural use. It is a grouping of subclasses that have the same relative degree of limitation of hazard. The limitation or hazard becomes progressively greater from Class 1 to Class 7.

capability subclass (soils): This is a grouping of soils with similar kinds of limitations and hazards. It provides information on the kind of conservation problem or limitation. The class and subclass together provide the map user with information about the degree and kind of limitation for broad land use planning and for the assessment of conservation needs.

cation: An ion carrying a positive charge of electricity; the common soil cations are calcium, magnesium, sodium, potassium, and hydrogen.

cation exchange capacity (CEC): A measure of the total amount of exchangeable cations that can be held by the soil; it is expressed in terms of mols per kg of soil (formerly me/100g).

Chernozemic: An order of soils that have developed under xerophytic or mesophytic grasses and forbs, or under grassland-forest transition vegetation, in cool to cold, subarid to subhumid climates. The soils have a dark-coloured surface (Ah, Ahe or Ap) horizon and a B or C horizon, or both, of high base saturation. The order consists of the Brown, Dark Brown, Black and Dark Gray great groups.

classification (soil): The systematic arrangement of soils into categories and classes on the basis of their characteristics. Broad groupings are made on the basis of general characteristics and subdivisions on the basis of more detailed differences in specific properties.

clay: As a particle-size term: a size fraction <0.002 mm equivalent diameter.

coarse fragments: Rock or mineral particles >2.0 mm in diameter.

coarse texture: The texture exhibited by sands, loamy sands, and sandy loams except very fine sandy loam. A soil containing large quantities of these textural classes.

consistency: (i) The resistance of a material to deformation or rupture.
(ii) The degree of cohesion or adhesion of the soil mass. Terms used to describe a moist soil are - loose, very friable, friable, firm, very firm, compact, very compact, and extremely compact. Terms used to describe dry soils are - loose, soft, slightly hard, hard, very hard and extremely hard.

control section: The vertical section of soil upon which the classification is based.

For mineral soils in general, the control section extends either from the mineral surface to 25 cm below the upper boundary of the C or IIC, or to a depth of 2 m, whichever is less. Exceptions are: (i) if the upper boundary of the C or IIC is less than 75 cm from the mineral surface, the control section extends to a depth of 1 m; (ii) if bedrock occurs at a depth of less than 1 m, the control section is from the surface to the lithic contact.

disturbed land: Land on which excavation has occurred or upon which overburden has been deposited, or both.

drainage: Soil drainage refers to the frequency and duration of periods when the soil is not saturated. Terms used are - excessively, well, moderately, imperfectly and poorly drained.

droughty soil: Sandy or very rapidly drained soil.

electrical conductivity (EC): A physical quantity which measures the readiness with which a medium conducts electricity. EC can be related to the soluble salt content of saturated soil extracts, and is expressed as dS/m or (mmhos/cm) at 25 degrees C.

aeolian: Material that has been deposited by wind action.

erosion: The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep.

exchangeable sodium percentage (ESP): The degree of saturation of the soil cation exchange complex with sodium. It may be calculated by the formula:

$$ESP = \frac{\text{Exchangeable Sodium}}{\text{Cation Exchange Capacity}} \times 100$$

Units are usually expressed as milliequivalents per 100 g soil.

fine texture: Consisting of or containing large quantities of the fine fractions, particularly of silt and clay.

first lift: The uppermost layer of undisturbed soil materials removed and segregated during surface mining to be respread as topsoil.

flood plain: The land bordering a stream, built up of sediments from overflow of the stream and subject to inundation when the stream is at flood stage.

fluvial: Material that has been transported and deposited by streams and rivers. Also alluvial.

friable: A consistency term pertaining to the ease of crumbling of soils.

fritted: Soil structure that is artificially created by tumbling mechanical action, as on a conveyor belt, that results in rounded moderately stable soil aggregates.

groundwater: That portion of the total precipitation which at any particular time is either passing through or standing in the soil and the underlying strata and is free to move under the influence of gravity.

Gleysolic: An order of soils developed under wet conditions and permanent or periodic reduction. These soils have low chromas, or prominent mottling, or both, in some horizons. The great groups Gleysol, Humic Gleysol and Luvic Gleysol are included in the order.

horizon (soil): A layer of mineral or organic soil or soil material approximately parallel to the land surface that has characteristics altered by processes of soil formation. It differs from adjacent horizons in properties such as colour, structure, texture, and consistence, and in chemical, biological, and mineralogical composition. The other layers are either nonsoil layers such as rock and water or layers of unconsolidated material considered to be unaffected by soil-forming processes.

hydraulic conductivity: The rate of flow of water through a given cross section of area under hydraulic gradient at the prevailing temperature.

immature soil: A soil with indistinct or only slightly developed horizons.

impeded drainage: A condition which hinders the movement of water through soils under the influence of gravity.

impervious: Resistant to penetration by fluids or by roots.

indicator plants: Plants characteristic of specific soil or site conditions.

infiltration: The downward entry of water into the soil.

irrigation: The artificial application of water to the soil for the benefit of growing crops.

lacustrine: Material deposited in lake water and later exposed.

landscape: All the natural features such as fields, hills, forests, water, etc., which distinguish one part of the earth's surface from another part. Usually that portion of land or territory which the eye can comprehend in a single view, including all its natural characteristics.

leachate: A solution obtained by leaching, for example, water that has percolated through soil containing soluble substances and that contains amounts of these substances in solution.

leaching: The removal of materials in solution by the passage of water through the soil.

loam: See soil texture. A mixture of sand, silt and clay.

loose: A soil consistency term.

Luvisol: An order of soils that have eluvial (Ae) horizons, and illuvial (Bt) horizons in which silicate clay is the main accumulation product. The soils developed under forest of forest-grassland transition in a moderate to cool climate. The Gray Luvisol great group is the most common in western Canada.

morphology (soil): The make up of the soil, including texture, structure, consistence, colour, and other mineralogical, physical and biological properties of the various horizons of the soil profile.

neutral soil: A soil in which the surface layer, at least to normal plow depth, is neither acid nor alkaline in reaction.

nonsoil: The aggregate of surficial materials that do not meet the definition of soil. It includes unconsolidated materials displaced by processes such as dumps of earth fill along a highway under construction, mineral or organic material thinner than 10 cm overlying bedrock, exposed bedrock, unconsolidated material covered by more than 60 cm of water year round, and organic material thinner than 40 cm overlying water.

nutrient: A chemical element or inorganic compound taken in by a green plant and used in organic synthesis.

Organic: An order of soils that have developed dominantly from organic deposits. The majority of organic soils are saturated for most of the year, unless artificially drained. The great groups include Fibrisol, Mesisol, Humisol and Folisol.

organic matter: The decomposition residues of biological materials derived from: (a) plant and animal materials deposited on the surface of the soils; and (b) roots and micro-organisms that decay beneath the surface of the soil.

overburden: Undisturbed consolidated or unconsolidated materials overlying a resource to be mined.

paralithic: Poorly consolidated bedrock which can be dug with a spade when moist. It is severely constraining but not impenetrable to roots.

parent material: The unconsolidated and more or less chemically weathered mineral or organic matter from which the solum of a soil is developed by pedogenic processes.

particle size: The effective diameter of a particle measured by sedimentation, sieving, or micrometric methods.

percolation (soil water): The downward movement of water through soil. Especially, the downward flow of water in saturated or nearly saturated soil at hydraulic gradients of the order of 1.0 or less.

permeability: The ease with which water can pass through a bulk mass of soil or a layer of soil. This can be either a qualitative term, or a quantitative term if the rate of movement is specified.

pH (soil): The negative logarithm of the hydrogen-ion activity of a soil. The degree of acidity (or alkalinity) of a soil as determined by means of glass, quinhydrone, or other suitable electrode or indicator at a specified moisture content of soil-water ratio, and expressed in terms of the pH scale.

platy: Consisting of soil aggregates that are developed predominately along the horizontal axes, laminated; flaky.

perviousness: The potential of a soil to transmit water internally, as inferred from soil characteristics such as structure, texture, porosity, cracks, organic matter content, and shrink-swell properties. It is closely related to measures of permeability, percolation rate, and infiltration rate, but these are reserved for actual measurements using standard techniques.

1. Rapidly pervious - the capacity to transmit water vertically is so great that the soil will remain wet for no more than a few hours after thorough wetting. The horizons and soils have large and continuous or connecting pores and cracks that do not close with wetting.

2. Moderately pervious - the capacity to transmit water vertically is great enough that the soil will remain saturated for no more than a few days after thorough wetting. Most moderately pervious soils hold relatively large amounts of water against the force of gravity, and are considered good, physically, for rooting and supplying water to plants. Soil horizons may be granular, blocky, weakly platy or massive (but porous) if continuous conducting pores or cracks are present which do not close with wetting.

3. Slowly pervious - the potential to transmit water vertically is so slow that the horizon or the soil will remain saturated for long periods of a week or more after thorough wetting. The soil may be massive, blocky, or platy, but connecting pores that conduct water when the soil is wet are few, and cracks or spaces among peds that may be present when the soil is dry, close with wetting. Even in positions accessible to plant roots, roots are usually few or absent. When present, roots are localized along cracks.

porosity: The volume percentage of the total bulk not occupied by solid particles.

profile (soil): A vertical section of the soil through all its horizons and extending into the parent material.

reaction (soils): The degree of acidity or alkalinity of soil, usually expressed as a pH value.

reconstructed soil: A soil profile formed by selected placement of suitable overburden materials on reshaped spoils.

residual material: Unconsolidated and partly weathered mineral materials accumulated by disintegration of consolidated rock in place.

root zone: That part of the soil which is occupied by plant roots.

sodium adsorption ratio (SAR): A ratio for soil extracts and irrigation waters used to express the relative activity of sodium ions in exchange relations with soil, where the ionic concentrations are expressed in milliequivalents per litre.

$$SAR = \frac{Na^+}{\sqrt{(Ca^{++} + Mg^{++}) / 2}}$$

saline soil: A nonalkali soil containing soluble salts in such quantities that they interfere with the growth of most crop plants. The conductivity of the saturation extract is greater than 4 dS/m (formerly mmhos/cm), the exchangeable-sodium percentage is less than 15, and the pH is usually less than 8.5.

salinization: The process of accumulation of salts in soils.

sand: A soil particle between 0.05 and 2.0 mm in diameter.

saturation extract: The solution extracted from a saturated soil paste prepared using distilled water.

saturation percentage: The amount of water required to saturate a unit of soil (often correlated with sodicity).

second lift: The second layer of undisturbed soil material which underlies the first lift, and which is removed and segregated during surface mining to be replaced as subsoil.

silt: A soil separate consisting of particles between 0.05 to 0.002 mm in equivalent diameter.

soil: The naturally occurring, unconsolidated mineral or organic material at least 10 cm thick, that occurs at the earth's surface and is capable of supporting plants. It includes disturbance of the surface by man's activities such as cultivation and logging but not displaced materials such as mine spoils.

sodicity: A measure of the amount of sodium on the exchange complex (often expressed as sodium adsorption ratio - SAR).

soil map: A map showing the distribution of soil types or other soil mapping units in relation to the prominent physical and cultural features of the earth's surface.

soil moisture: Water contained in the soil.

- soil structure:** The combination or arrangement of primary soil particles into secondary particles, unit or peds. These secondary units may be, but usually are not, arranged in the profile in such a manner as to give a distinctive characteristics pattern. The secondary units are characterized and classified on the basis of size, shape, and degree of distinctness into classes, types, and grades, respectively. Common terms for kind of structure are - single grain, amorphous, blocky, subangular blocky, granular, platy, prismatic and columnar.
- soil survey:** The systematic examination, description, classification, and mapping of soils in an area. Soil surveys are ranked according to the kind and intensity of field examination.
- Solonetzcic:** An order of soils developed mainly under grass or grass-forest vegetative cover in semiarid to subhumid climates. The soils have a stained brownish or blackish solonetzic B (Bn, Bnt) horizon and a saline C horizon. The order includes the Solonetz, Solodized Solonetz and Solod great groups.
- solum (plural sola):** The upper horizons of a soil in which the parent material has been modified and within which most plant roots are confined. It consists usually of A and B horizons.
- spoil:** Overburden that has been disturbed and haphazardly mixed during surface mining.
- subsoil:** Although a common term it cannot be defined accurately. It may be the B horizon of a soil with a distinct profile. It can also be defined as the zone below the plowed soil in which roots normally grow. In this publication it refers to the soil material between 20 cm and 100 cm depth.
- texture:** The relative proportions of sand, silt and clay (the soil separates). It is described in terms such as sand (S), loamy sand (LS), sand loam (SL), loam (L), silt loam (SiL), clay loam (CL), silty clay loam (SiCL) and clay (C). See textural triangle, Figure 21.
- topsoil:** The organo-mineral surface "A" or organic surface "O" horizon; dark-coloured surface soil materials, used synonymously with first lift. First lift materials are usually removed to the depth of the first easily-identified colour change, or to specified depth where colour change is poor, and contain the soil Ah, Ap, O, or Ahe horizon. Other horizons may be included in the first lift if specified.
- unconsolidated material:** Includes loose material as well as that compacted or cemented by soil-forming processes.
- water-holding capacity:** The ability of the soil (or spoil material) to hold water. Water content may be expressed as either gravimetric water or volumetric water. Gravimetric water is expressed as percentage of the weight of water per unit weight of oven-dry soil. Volumetric water can be expressed as percentage of the volume of water per unit volume of soil or as depth of water per unit depth of soil.

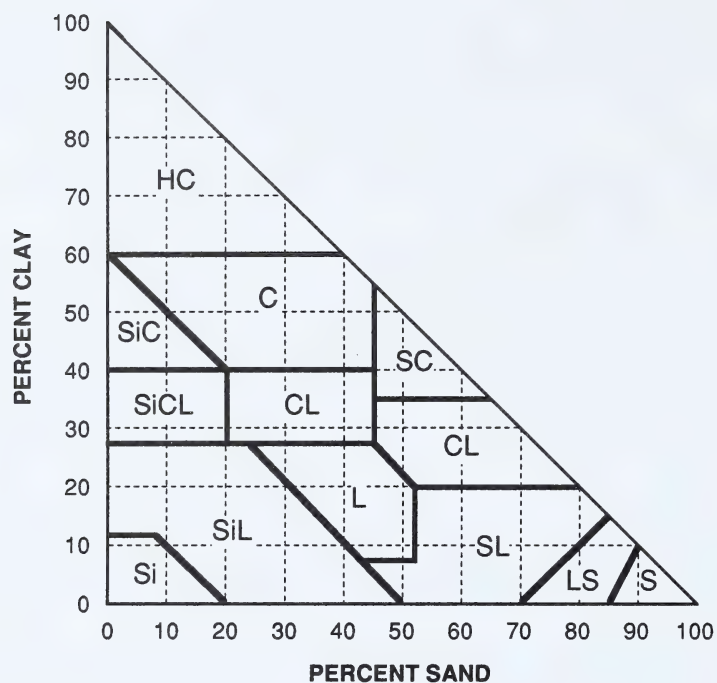


Figure 21. Soil textural triangle.

<u>Soil Index</u>	<u>Class</u>
80 - 100	1
60 - 79	2
45 - 59	3
30 - 44	4
20 - 29	5
10 - 19	6
0 - 9	7

RECLAMATION RESEARCH REPORTS

1. **RRTAC 79-2: Proceedings: Workshop on Native Shrubs in Reclamation.** P.F. Ziemkiewicz, C.A. Dermott and H.P. Sims (Editors). 104 pp. No longer available.

The Workshop was organized as the first step in developing a Native Shrub reclamation research program. The Workshop provided a forum for the exchange of information and experiences on three topics: propagation; out-planting; and, species selection.

2. **RRTAC 80-1: Test Plot Establishment: Native Grasses for Reclamation.** R.S. Sadasivaiah and J. Weijer. 19 pp. No longer available.

The report details the species used at three test plots in Alberta's Eastern Slopes. Site preparation, experimental design, and planting method are also described.

3. **RRTAC 80-2: Alberta's Reclamation Research Program - 1979.** Reclamation Research Technical Advisory Committee. 22 pp. No longer available.

This report describes the expenditure of \$1,190,006 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

4. **RRTAC 80-3: The Role of Organic Compounds in Salinization of Plains Coal Mining Sites.** N.S.C. Cameron et al. 46 pp. No longer available.

This is a literature review of the chemistry of sodic mine spoil and the changes expected to occur in groundwater.

5. **RRTAC 80-4: Proceedings: Workshop on Reconstruction of Forest Soils in Reclamation.** P.F. Ziemkiewicz, S.K. Takyi and H.F. Regier (Editors). 160 pp. \$10.00

Experts in the field of forestry and forest soils report on research relevant to forest soil reconstruction and discuss the most effective means of restoring forestry capability of mined lands.

6. **RRTAC 80-5: Manual of Plant Species Suitability for Reclamation in Alberta.** L.E. Watson, R.W. Parker and D.F. Polster. 2 vols, 541 pp. No longer available; replaced by RRTAC 89-4.

Forty-three grass, fourteen forb, and thirty-four shrub and tree species are assessed in terms of their suitability for use in reclamation. Range maps, growth habit, propagation, tolerance, and availability information are provided.

7. **RRTAC 81-1: The Alberta Government's Reclamation Research Program - 1980.** Reclamation Research Technical Advisory Committee. 25 pp. No longer available.

This report describes the expenditure of \$1,455,680 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

8. **RRTAC 81-2: 1980 Survey of Reclamation Activities in Alberta.** D.G. Walker and R.L. Rothwell. 76 pp. \$10.00

This survey is an update of a report prepared in 1976 on reclamation activities in Alberta, and includes research and operational reclamation, locations, personnel, etc.

9. **RRTAC 81-3: Proceedings: Workshop on Coal Ash and Reclamation.** P.F. Ziemkiewicz, R. Stein, R. Leitch and G. Lutwick (Editors). 253 pp. \$10.00

Presents nine technical papers on the chemical, physical, and engineering properties of Alberta fly and bottom ashes, revegetation of ash disposal sites, and use of ash as a soil amendment. Workshop discussions and summaries are also included.

10. **RRTAC 82-1: Land Surface Reclamation: An International Bibliography.** H.P. Sims and C.B. Powter. 2 vols, 292 pp. \$10.00

Literature to 1980 pertinent to reclamation in Alberta is listed in Vol. 1 and is also on the University of Alberta computing system (in a SPIRES database called RECLAIM). Vol. 2 comprises the keyword index and computer access manual.

11. **RRTAC 82-2: A Bibliography of Baseline Studies in Alberta: Soils, Geology, Hydrology and Groundwater.** C.B. Powter and H.P. Sims. 97 pp. \$5.00

This bibliography provides baseline information for persons involved in reclamation research or in the preparation of environmental impact assessments. Materials, up to date as of December 1981, are available in the Alberta Environment Library.

12. **RRTAC 82-3: The Alberta Government's Reclamation Research Program - 1981.** Reclamation Research Technical Advisory Committee. 22 pp. No longer available.

This report describes the expenditure of \$1,499,525 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

13. **RRTAC 83-1: Soil Reconstruction Design for Reclamation of Oil Sand Tailings.** Monenco Consultants Ltd. 185 pp. No longer available

Volumes of peat and clay required to amend oil sand tailings were estimated based on existing literature. Separate soil prescriptions were made for spruce, jack pine, and herbaceous cover types. The estimates form the basis of field trials (See RRTAC 92-4).

14. **RRTAC 83-2: The Alberta Government's Reclamation Research Program - 1982.** Reclamation Research Technical Advisory Committee. 25 pp. No longer available.

This report describes the expenditure of \$1,536,142 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

15. **RRTAC 83-3: Evaluation of Pipeline Reclamation Practices on Agricultural Lands in Alberta.** Hardy Associates (1978) Ltd. 205 pp. No longer available.

Available information on pipeline reclamation practices was reviewed. A field survey was then conducted to determine the effects of pipe size, age, soil type, construction method, etc. on resulting crop production.

16. **RRTAC 83-4: Proceedings: Effects of Coal Mining on Eastern Slopes Hydrology.** P.F. Ziemkiewicz (Editor). 123 pp. \$10.00

Technical papers are presented dealing with the impacts of mining on mountain watersheds, their flow characteristics, and resulting water quality. Mitigative measures and priorities were also discussed.

17. **RRTAC 83-5: Woody Plant Establishment and Management for Oil Sands Mine Reclamation.** Techman Engineering Ltd. 124 pp. No longer available.

This is a review and analysis of information on planting stock quality, rearing techniques, site preparation, planting, and procedures necessary to ensure survival of trees and shrubs in oil sand reclamation.

18. **RRTAC 84-1: Land Surface Reclamation: A Review of the International Literature.** H.P. Sims, C.B. Powter and J.A. Campbell. 2 vols, 1549 pp. \$20.00

Nearly all topics of interest to reclamationists including mining methods, soil amendments, revegetation, propagation and toxic materials are reviewed in light of the international literature.

19. **RRTAC 84-2: Propagation Study: Use of Trees and Shrubs for Oil Sand Reclamation.** Techman Engineering Ltd. 58 pp. \$10.00

This report evaluates and summarizes all available published and unpublished information on large-scale propagation methods for shrubs and trees to be used in oil sand reclamation.

20. **RRTAC 84-3: Reclamation Research Annual Report - 1983.** P.F. Ziemkiewicz. 42 pp. \$5.00

This report describes the expenditure of \$1,529,483 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas and describes the projects funded under each program.

21. **RRTAC 84-4: Soil Microbiology in Land Reclamation.** D. Parkinson, R.M. Danielson, C. Griffiths, S. Visser and J.C. Zak. 2 vols, 676 pp. \$10.00

This is a collection of five reports dealing with re-establishment of fungal decomposers and mycorrhizal symbionts in various amended spoil types.

22. **RRTAC 85-1: Proceedings: Revegetation Methods for Alberta's Mountains and Foothills.** P.F. Ziemkiewicz (Editor). 416 pp. \$10.00.

Results of long-term experiments and field experience on species selection, fertilization, reforestation, topsoiling, shrub propagation and establishment are presented.

23. **RRTAC 85-2: Reclamation Research Annual Report - 1984.** P.F. Ziemkiewicz. 29 pp. No longer available.

This report describes the expenditure of \$1,320,516 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas and describes the projects funded under each program.

24. **RRTAC 86-1: A Critical Analysis of Settling Pond Design and Alternative Technologies.** A. Somani. 372 pp. \$10.00

The report examines the critical issue of settling pond design, and sizing and alternative technologies. The study was co-funded with The Coal Association of Canada.

25. **RRTAC 86-2: Characterization and Variability of Soil Reconstructed after Surface Mining in Central Alberta.** T.M. Macyk. 146 pp. No longer available.

Reconstructed soils representing different materials handling and replacement techniques were characterized, and variability in chemical and physical properties was assessed. The data obtained indicate that reconstructed soil properties are determined largely by parent material characteristics and further tempered by materials handling procedures. Mining tends to create a relatively homogeneous soil landscape in contrast to the mixture of diverse soils found before mining.

26. **RRTAC 86-3: Generalized Procedures for Assessing Post-Mining Groundwater Supply Potential in the Plains of Alberta - Plains Hydrology and Reclamation Project.** M.R. Trudell and S.R. Moran. 30 pp. \$5.00

In the Plains region of Alberta, the surface mining of coal generally occurs in rural, agricultural areas in which domestic water supply requirements are met almost entirely by groundwater. Consequently, an important aspect of the capability of reclaimed lands to satisfy the needs of a residential component is the post-mining availability of groundwater. This report proposes a sequence of steps or procedures to identify and characterize potential post-mining aquifers.

27. **RRTAC 86-4: Geology of the Battle River Site: Plains Hydrology and Reclamation Project.** A. Maslowski-Schutze, R. Li, M. Fenton and S.R. Moran. 86 pp. \$10.00

This report summarizes the geological setting of the Battle River study site. It is designed to provide a general understanding of geological conditions adequate to establish a framework for hydrogeological and general reclamation studies. The report is not intended to be a detailed synthesis such as would be required for mine planning purposes.

28. **RRTAC 86-5: Chemical and Mineralogical Properties of Overburden: Plains Hydrology and Reclamation Project.** A. Maslowski-Schutze. 71 pp. \$10.00

This report describes the physical and mineralogical properties of overburden materials in an effort to identify individual beds within the bedrock overburden that might be significantly different in terms of reclamation potential.

29. **RRTAC 86-6: Post-Mining Groundwater Supply at the Battle River Site: Plains Hydrology and Reclamation Project.** M.R. Trudell, G.J. Sterenberg and S.R. Moran. 49 pp. \$5.00

The report deals with the availability of water supply in or beneath cast overburden to support post-mining land use, including both quantity and quality considerations. The study area is in the Battle River Mining area in east-central Alberta.

30. **RRTAC 86-7: Post-Mining Groundwater Supply at the Highvale Site: Plains Hydrology and Reclamation Project.** M.R. Trudell. 25 pp. \$5.00

This report evaluates the availability of water supply in or beneath cast overburden to support post-mining land use, including both quantity and quality considerations. The study area is the Highvale mining area in west-central Alberta.

31. **RRTAC 86-8: Reclamation Research Annual Report - 1985.** P.F. Ziemkiewicz. 54 pp. \$5.00

This report describes the expenditure of \$1,168,436 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas and describes the projects funded under each program.

32. **RRTAC 86-9: Wildlife Habitat Requirements and Reclamation Techniques for the Mountains and Foothills of Alberta.** J.E. Green, R.E. Salter and D.G. Walker. 285 pp. No longer available.

This report presents a review of relevant North American literature on wildlife habitats in mountain and foothills biomes, reclamation techniques, potential problems in wildlife habitat reclamation, and potential habitat assessment methodologies. Four biomes (Alpine, Subalpine, Montane, and Boreal Uplands) and 10 key wildlife species (snowshoe hare, beaver, muskrat, elk, moose, caribou, mountain goat, bighorn sheep, spruce grouse, and white-tailed ptarmigan) are discussed. The study was co-funded with The Coal Association of Canada.

33. **RRTAC 87-1: Disposal of Drilling Wastes.** L.A. Leskiw, E. Reinl-Dwyer, T.L. Dabrowski, B.J. Rutherford and H. Hamilton. 210 pp. No longer available.

Current drilling waste disposal practices are reviewed and criteria in Alberta guidelines are assessed. The report also identifies research needs and indicates mitigation measures. A manual provides a decision-making flowchart to assist in selecting methods of environmentally safe waste disposal.

34. **RRTAC 87-2: Minesoil and Landscape Reclamation of the Coal Mines in Alberta's Mountains and Foothills.** A.W. Fedkenheuer, L.J. Knapik and D.G. Walker. 174 pp. No longer available.

This report reviews current reclamation practices with regard to site and soil reconstruction and re-establishment of biological productivity. It also identifies research needs in the Mountain-Foothills area. The study was co-funded with The Coal Association of Canada.

35. **RRTAC 87-3: Gel and Saline Drilling Wastes in Alberta: Workshop Proceedings.** D.A. Lloyd (Compiler). 218 pp. No longer available.

Technical papers were presented which describe: mud systems used and their purpose; industrial constraints; government regulations, procedures and concerns; environmental considerations in waste disposal; and toxic constituents of drilling wastes. Answers to a questionnaire distributed to participants are included in an appendix.

36. **RRTAC 87-4: Reclamation Research Annual Report - 1986.** 50 pp. No longer available.

This report describes the expenditure of \$1,186,000 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas and describes the projects funded under each program.

37. **RRTAC 87-5: Review of the Scientific Basis of Water Quality Criteria for the East Slope Foothills of Alberta.** Beak Associates Consulting Ltd. 46 pp. \$10.00

The report reviews existing Alberta guidelines to assess the quality of water drained from coal mine sites in the East Slope Foothills of Alberta. World literature was reviewed within the context of the East Slopes environment and current mining operations. The ability of coal mine operators to meet the various guidelines is discussed. The study was co-funded with The Coal Association of Canada.

38. **RRTAC 87-6: Assessing Design Flows and Sediment Discharge on the Eastern Slopes.** Hydrocon Engineering (Continental) Ltd. and Monenco Consultants Ltd. 97 pp. \$10.00

The report provides an evaluation of current methodologies used to determine sediment yields due to rainfall events in well-defined areas. Models are available in Alberta to evaluate water and sediment discharge in a post-mining situation. SEDIMOT II (Sedimentology Disturbed Modelling Techniques) is a single storm model that was developed specifically for the design of sediment control structures in watersheds disturbed by surface mining and is well suited to Alberta conditions. The study was co-funded with The Coal Association of Canada.

39. **RRTAC 87-7: The Use of Bottom Ash as an Amendment to Sodic Spoil.** S. Fullerton. 83 pp. No longer available.

The report details the use of bottom ash as an amendment to sodic coal mine spoil. Several rates and methods of application of bottom ash to sodic spoil were tested to determine which was the best at reducing the effects of excess sodium and promoting crop growth. Field trials were set up near the Vesta mine in East Central Alberta using ash readily available from a nearby coal-fired thermal generating station. The research indicated that bottom ash incorporated to a depth of 30 cm using a subsoiler provided the best results.

40. **RRTAC 87-8: Waste Dump Design for Erosion Control.** R.G. Chopiuk and S.E. Thornton. 45 pp. \$5.00

This report describes a study to evaluate the potential influence of erosion from reclaimed waste dumps on downslope environments such as streams and rivers. Sites were selected from coal mines in Alberta's mountains and foothills, and included resloped dumps of different configurations and ages, and having different vegetation covers. The study concluded that the average annual amount of surface erosion is minimal. As expected, erosion was greatest on slopes which were newly regraded. Slopes with dense grass cover showed no signs of erosion. Generally, the amount of erosion decreased with time, as a result of initial loss of fine particles, the formation of a weathered surface, and increased vegetative cover.

41. **RRTAC 87-9: Hydrogeology and Groundwater Chemistry of the Battle River Mining Area.**
M.R. Trudell, R.L. Faught and S.R. Moran. 97 pp. No longer available.

This report describes the premining geologic conditions in the Battle River coal mining area including the geology as well as the groundwater flow patterns, and the groundwater quality of a sequence of several water-bearing formations extending from the surface to a depth of about 100 metres.

42. **RRTAC 87-10: Soil Survey of the Plains Hydrology and Reclamation Project - Battle River Project Area.** T.M. Macyk and A.H. MacLean. 62 pp. plus 8 maps. \$10.00

The report evaluates the capability of post-mining landscapes and assesses the changes in capability as a result of mining, in the Battle River mining area. Detailed soils information is provided in the report for lands adjacent to areas already mined as well as for lands that are destined to be mined. Characterization of the reconstructed soils in the reclaimed areas is also provided. Data were collected from 1979 to 1985. Eight maps supplement the report.

43. **RRTAC 87-11: Geology of the Highvale Study Site: Plains Hydrology and Reclamation Project.**
A. Maslowski-Schutze. 78 pp. \$10.00

The report is one of a series that describes the geology, soils and groundwater conditions at the Highvale Coal Mine study site. The purpose of the study was to establish a summary of site geology to a level of detail necessary to provide a framework for studies of hydrogeology and reclamation.

44. **RRTAC 87-12: Premining Groundwater Conditions at the Highvale Site.** M.R. Trudell and R. Faught. 83 pp. No longer available.

This report presents a detailed discussion of the premining flow patterns, hydraulic properties, and isotopic and hydrochemical characteristics of five layers within the Paskapoo Geological Formation, the underlying sandstone beds of the Upper Horseshoe Canyon Formation, and the surficial glacial drift.

45. **RRTAC 87-13: An Agricultural Capability Rating System for Reconstructed Soils.** T.M. Macyk. 27 pp. \$5.00

This report provides the rationale and a system for assessing the agricultural capability of reconstructed soils. Data on the properties of the soils used in this report are provided in RRTAC 86-2.

46. **RRTAC 88-1: A Proposed Evaluation System for Wildlife Habitat Reclamation in the Mountains and Foothills Biomes of Alberta: Proposed Methodology and Assessment Handbook.**
T.R. Eccles, R.E. Salter and J.E. Green. 101 pp. plus appendix. \$10.00

The report focuses on the development of guidelines and procedures for the assessment of reclaimed wildlife habitat in the Mountains and Foothills regions of Alberta. The technical section provides background documentation including a discussion of reclamation planning, a listing of reclamation habitats and associated key wildlife species, conditions required for development, recommended revegetation species, suitable reclamation techniques, a description of the recommended assessment techniques and a glossary of basic terminology. The assessment handbook section contains basic information necessary for evaluating wildlife habitat reclamation, including assessment scoresheets for 15 different reclamation habitats, standard methodologies for measuring habitat variables used as assessment criteria, and minimum requirements for certification. This handbook is intended as a field manual that could potentially be used by site operators and reclamation officers. The study was co-funded with The Coal Association of Canada.

47. **RRTAC 88-2: Plains Hydrology and Reclamation Project: Spoil Groundwater Chemistry and its Impacts on Surface Water.** M.R. Trudell (Compiler). 135 pp. No longer available.

Two reports comprise this volume. The first "Chemistry of Groundwater in Mine Spoil, Central Alberta," describes the chemical make-up of spoil groundwater at four mines in the Plains of Alberta. It explains the nature and magnitude of changes in groundwater chemistry following mining and reclamation. The second report, "Impacts of Surface Mining on Chemical Quality of Streams in the Battle River Mining Area," describes the chemical quality of water in streams in the Battle River mining area, and the potential impact of groundwater discharge from surface mines on these streams.

48. **RRTAC 88-3: Revegetation of Oil Sands Tailings: Growth Improvement of Silver-berry and Buffalo-berry by Inoculation with Mycorrhizal Fungi and N₂-Fixing Bacteria.** S. Visser and R.M. Danielson. 98 pp. \$10.00

The report provides results of a study: (1) To determine the mycorrhizal affinities of various actinorrhizal shrubs in the Fort McMurray, Alberta region; (2) To establish a basis for justifying symbiont inoculation of buffalo-berry and silver-berry; (3) To develop a growing regime for the greenhouse production of mycorrhizal, nodulated silver-berry and buffalo-berry; and, (4) To conduct a field trial on reconstructed soil on the Syncrude Canada Limited oil sands site to critically evaluate the growth performance of inoculated silver-berry and buffalo-berry as compared with their un-inoculated counterparts.

49. **RRTAC 88-4: Plains Hydrology and Reclamation Project: Investigation of the Settlement Behaviour of Mine Backfill.** D.R. Pauls (compiler). 135 pp. \$10.00

This three part volume covers the laboratory assessment of the potential for subsidence in reclaimed landscapes. The first report in this volume, "Simulation of Mine Spoil Subsidence by Consolidation Tests," covers laboratory simulations of the subsidence process particularly as it is influenced by resaturation of mine spoil. The second report, "Water Sensitivity of Smectitic Overburden: Plains Region of Alberta," describes a series of laboratory tests to determine the behaviour of overburden materials when brought into contact with water. The report entitled "Classification System for Transitional Materials: Plains Region of Alberta," describes a lithological classification system developed to address the characteristics of the smectite rich, clayey transition materials that make up the overburden in the Plains of Alberta.

50. **RRTAC 88-5: Ectomycorrhizae of Jack Pine and Green Alder: Assessment of the Need for Inoculation, Development of Inoculation Techniques and Outplanting Trials on Oil Sand Tailings.** R.M. Danielson and S. Visser. 177 pp. No longer available.

The overall objective of this research was to characterize the mycorrhizal status of Jack Pine and Green Alder which are prime candidates as reclamation species for oil sand tailings and to determine the potential benefits of mycorrhizae on plant performance. This entailed determining the symbiont status of container-grown nursery stock and the quantity and quality of inoculum in reconstructed soils, developing inoculation techniques and finally, performance testing in an actual reclamation setting.

51. **RRTAC 88-6: Reclamation Research Annual Report - 1987. Reclamation Research Technical Advisory Committee.** 67 pp. No longer available.

This annual report describes the expenditure of \$500,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

- 52. RRTAC 88-7: Baseline Growth Performance Levels and Assessment Procedure for Commercial Tree Species in Alberta's Mountains and Foothills. W.R. Dempster and Associates Ltd. 66 pp. \$5.00**

Data on juvenile height development of lodgepole pine and white spruce from cut-over or burned sites in the Eastern Slopes of Alberta were used to define reasonable expectations of early growth performance as a basis for evaluating the success of reforestation following coal mining. Equations were developed predicting total seedling height and current annual height increment as a function of age and elevation. Procedures are described for applying the equations, with further adjustments for drainage class and aspect, to develop local growth performance against these expectations. The study was co-funded with The Coal Association of Canada.

- 53. RRTAC 88-8: Alberta Forest Service Watershed Management Field and Laboratory Methods. A.M.K. Nip and R.A. Hursey. 4 Sections, various pagings. \$10.00**

Disturbances such as coal mines in the Eastern Slopes of Alberta have the potential for affecting watershed quality during and following mining. The collection of hydrometric, water quality and hydrometeorologic information is a complex task. A variety of instruments and measurement methods are required to produce a record of hydrologic inputs and outputs for a watershed basin. There is a growing awareness and recognition that standardization of data acquisition methods is required to ensure data comparability, and to allow comparison of data analyses. The purpose of this manual is to assist those involved in the field of data acquisition by outlining methods, practices and instruments which are reliable and recognized by the International Organization for Standardization.

- 54. RRTAC 88-9: Computer Analysis of the Factors Influencing Groundwater Flow and Mass Transport in a System Disturbed by Strip Mining. F.W. Schwartz and A.S. Crowe. 78 pp. No longer available.**

Work presented in this report demonstrates how a groundwater flow model can be used to study a variety of mining-related problems such as declining water levels in areas around the mine as a result of dewatering, and the development of high water tables in spoil once resaturation is complete. This report investigates the role of various hydrogeological parameters that influence the magnitude, timing, and extent of water level changes during and following mining at the regional scale. The modelling approach described here represents a major advance on existing work.

- 55. RRTAC 88-10: Review of Literature Related to Clay Liners for Sump Disposal of Drilling Wastes. D.R. Pauls, S.R. Moran and T. Macyk. 61 pp. No longer available.**

The report reviews and analyses the effectiveness of geological containment of drilling waste in sumps. Of particular importance was the determination of changes in properties of clay materials as a result of contact with highly saline brines containing various organic chemicals.

- 56. RRTAC 88-11: Highvale Soil Reconstruction Project: Five Year Summary. D.N. Graveland, T.A. Oddie, A.E. Osborne and L.A. Panek. 104 pp. \$10.00**

This report provides details of a five year study to determine a suitable thickness of subsoil to replace over minespoil in the Highvale plains coal mine area to ensure return of agricultural capability. The study also examined the effect of slope and aspect on agricultural capability. This study was funded and managed with industry assistance.

57. **RRTAC 88-12: A Review of the International Literature on Mine Spoil Subsidence.** J.D. Scott, G. Zinter, D.R. Pauls and M.B. Dusseault. 36 pp. \$10.00

The report reviews available engineering literature relative to subsidence of reclaimed mine spoil. The report covers methods for site investigation, field monitoring programs and lab programs, mechanisms of settlement, and remedial measures.

58. **RRTAC 89-1: Reclamation Research Annual Report - 1988.** 74 pp. \$5.00

This annual report describes the expenditure of \$280,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

59. **RRTAC 89-2: Proceedings of the Conference: Reclamation, A Global Perspective.** D.G. Walker, C.B. Powter and M.W. Pole (Compilers). 2 Vols., 854 pp. No longer available.

Over 250 delegates from all over the world attended this conference held in Calgary in August, 1989. The proceedings contains over 85 peer-reviewed papers under the following headings: A Global Perspective; Northern and High Altitude Reclamation; Fish & Wildlife and Rangeland Reclamation; Water; Herbaceous Revegetation; Woody Plant Revegetation and Succession; Industrial and Urban Sites; Problems and Solutions; Sodic and Saline Materials; Soils and Overburden; Acid Generating Materials; and, Mine Tailings.

60. **RRTAC 89-3: Efficiency of Activated Charcoal for Inactivation of Bromacil and Tebuthiuron Residues in Soil.** M.P. Sharma. 38 pp. ISBN 0-7732-0878-X. \$5.00

Bromacil and Tebuthiuron were commonly used soil sterilants on well sites, battery sites and other industrial sites in Alberta where total vegetation control was desired. Activated charcoal was found to be effective in binding the sterilants in greenhouse trials. The influence of factors such as herbicide:charcoal concentration ratio, soil texture, organic matter content, soil moisture, and the time interval between charcoal incorporation and plant establishment were evaluated in the greenhouse.

61. **RRTAC 89-4: Manual of Plant Species Suitability for Reclamation in Alberta - 2nd Edition.** Hardy BBT Limited. 436 pp. ISBN 0-7732-0882-8. \$10.00.

This is an updated version of RRTAC Report 80-5 which describes the characteristics of 43 grass, 14 forb and 34 shrub and tree species which make them suitable for reclamation in Alberta. The report has been updated in several important ways: a line drawing of each species has been added; the range maps for each species have been redrawn based on an ecosystem classification of the province; new information (to 1990) has been added, particularly in the sections on reclamation use; and the material has been reorganized to facilitate information retrieval. Of greatest interest is the performance chart that precedes each species and the combined performance charts for the grass, forb, and shrub/tree groups. These allow the reader to pick out at a glance species that may suit their particular needs. The report was produced with the assistance of a grant from the Recreation, Parks and Wildlife Foundation.

62. **RRTAC 89-5: Battle River Soil Reconstruction Project Five Year Summary.** L.A. Leskiw. 188 pp. No longer available.

This report summarizes the results of a five year study to investigate methods required to return capability to land surface mined for coal in the Battle River area of central Alberta. Studies were conducted on: the amounts of sub-soil required, the potential of gypsum and bottom ash to amend adverse soil properties, and the effects of slope angle and aspect. Forage and cereal crop growth was evaluated, as were changes in soil chemistry, density and moisture holding characteristics.

- 63. RRTAC 89-6: Detailed Sampling, Characterization and Greenhouse Pot Trials Relative to Drilling Wastes in Alberta.** T.M. Macyk, F.I. Nikiforuk, S.A. Abboud and Z.W. Widtman. 228 pp. No longer available.

This report summarizes a three-year study of the chemistry of freshwater gel, KCl, NaCl, DAP, and invert drilling wastes, both solids and liquids, from three regions in Alberta: Cold Lake, Eastern Slopes, and Peace River/Grande Prairie. A greenhouse study also examined the effects of adding various amounts of waste to soil on grass growth and soil chemistry. Methods for sampling drilling wastes are recommended.

- 64. RRTAC 89-7: A User's Guide for the Prediction of Post-Mining Groundwater Chemistry from Overburden Characteristics.** M.R. Trudell and D.C. Cheel. 55 pp. \$5.00

This report provides the detailed procedure and methodology that is required to produce a prediction of post-mining groundwater chemistry for plains coal mines, based on the soluble salt characteristics of overburden materials. The fundamental component of the prediction procedure is the geochemical model PHREEQE, developed by the U.S. Geological Survey, which is in the public domain and has been adapted for use on personal computers.

- 65. RRTAC 90-1: Reclamation Research Annual Report - 1989.** 62 pp. No longer available.

This annual report describes the expenditure of \$480,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

- 66. RRTAC 90-2: Initial Selection for Salt Tolerance in Rocky Mountain Accessions of Slender Wheatgrass and Alpine Bluegrass.** R. Hermesh, J. Woosaree, B.A. Darroch, S.N. Acharya and A. Smreciu. 40 pp. \$5.00

Selected lines of slender wheatgrass and alpine bluegrass collected from alpine and subalpine regions of Alberta as part of another native grass project were evaluated for their ability to emerge in a saline medium. Eleven slender wheatgrass and 72 alpine bluegrass lines had a higher percentage emergence than the Orbit Tall Wheatgrass control (a commonly available commercial grass). This means that as well as an ability to grow in high elevation areas, these lines may also be suitable for use in areas where saline soil conditions are present. Thus, their usefulness for reclamation has expanded.

- 67. RRTAC 90-3: Natural Plant Invasion into Reclaimed Oil Sands Mine Sites.** Hardy BBT Limited. 65 pp. \$5.00

Vegetation data from reclaimed sites on the Syncrude and Suncor oil sands mines have been summarized and related to site and factors and reclamation methods. Natural invasion into sites seeded to agronomic grasses and legumes was minimal even after 15 years. Invasion was slightly greater in sites seeded to native species, but was greatest on sites that were not seeded. Invasion was mostly from agronomic species and native forbs; native shrub and tree invasion was minimal.

68. **RRTAC 90-4: Physical and Hydrological Characteristics of Ponds in Reclaimed Upland Landscape Settings and their Impact on Agricultural Capability.** S.R. Moran, T.M. Macyk, M.R. Trudell and M.E. Pigot, Alberta Research Council. 76 pp. \$5.00

The report details the results and conclusions from studying a pond in a reclaimed upland site in Vesta Mine. The pond formed as a result of two factors: (1) a berm which channelled meltwater into a series of subsidence depressions, forming a closed basin; and (2) low hydraulic conductivity in the lower subsoil and upper spoil as a result of compaction during placement and grading which did not allow for rapid drainage of ponded water. Ponds such as this in the reclaimed landscape can affect agricultural capability by: (1) reducing the amount of farmable land (however, the area covered by these ponds in this region is less than half of that found in unmined areas); and, (2) creating the conditions necessary for the progressive development of saline and potentially sodic soils in the area adjacent to the pond.

69. **RRTAC 90-5: Review of the Effects of Storage on Topsoil Quality.** Thurber Consultants Ltd., Land Resources Network Ltd., and Norwest Soil Research Ltd. 116 pp. \$10.00

The international literature was reviewed to determine the potential effects of storage on topsoil quality. Conclusions from the review indicated that storage does not appear to have any severe and longterm effects on topsoil quality. Chemical changes may be rectified with the use of fertilizers or manure. Physical changes appear to be potentially less serious than changes in soil quality associated with the stripping and respreading operations. Soil biotic populations appear to revert to pre-disturbance levels of activity within acceptable timeframes. Broad, shallow storage piles that are seeded to acceptable grass and legume species are recommended; agrochemical use should be carefully controlled to ensure soil biota are not destroyed.

70. **RRTAC 90-6: Proceedings of the Industry/Government Three-Lift Soils Handling Workshop.** Deloitte & Touche. 168 pp. \$10.00

This report documents the results of a two-day workshop on the issue of three-lift soils handling for pipelines. The workshop was organized and funded by RRTAC, the Canadian Petroleum Association and the Independent Petroleum Association of Canada. Day one focused on presentation of government and industry views on the criteria for three-lift, the rationale and field data in support of three- and two-lift procedures, and an examination of the various soil handling methods in use. During day two, five working groups discussed four issues: alternatives to three-lift; interim criteria and suggested revisions; research needs; definitions of terms. The results of the workshop are being used by a government/industry committee to revise soils handling criteria for pipelines.

71. **RRTAC 90-7: Reclamation of Disturbed Alpine Lands: A Literature Review.** Hardy BBT Limited. 209 pp. \$10.00

This review covers current information from North American sources on measures needed to reclaim alpine disturbances. The review provides information on pertinent Acts and regulations with respect to development and environmental protection of alpine areas. It also discusses: alpine environmental conditions; current disturbances to alpine areas; reclamation planning; site and surface preparation; revegetation; and, fertilization. The report also provides a list of research and information needs for alpine reclamation in Alberta.

72. **RRTAC 90-8: Plains Hydrology and Reclamation Project: Summary Report.** S.R. Moran, M.R. Trudell, T.M. Macyk and D.B. Cheel. 105 pp. \$10.00

This report summarizes a 10-year study on the interactions of groundwater, soils and geology as they affect successful reclamation of surface coal mines in the plains of Alberta. The report covers: Characterization of the Battle River and Wabamun study areas; Properties of reclaimed materials and landscapes; Impacts of mining and reclamation on post-mining land use; and, Implications for reclamation practice and regulation. This project has led to the publication of 18 RRTAC reports and 22 papers in conference proceedings and referred journals.

73. RRTAC 90-9: Literature Review on the Disposal of Drilling Waste Solids. Monenco Consultants Limited. 83 pp. \$5.00

This report reviews the literature on, and government and industry experience with, burial of drilling waste solids in an Alberta context. The review covers current regulations in Alberta, other provinces, various states in the US and other countries. Definitions of various types of burial are provided, as well as brief summaries of other possible disposal methods. Environmental concerns with the various options are presented as well as limited information on costs and monitoring of burial sites. The main conclusion of the work is that burial is still a viable option for some waste types but that each site and waste type must be evaluated on its own merits.

74. RRTAC 90-10: Potential Contamination of Shallow Aquifers by Surface Mining of Coal. M.R. Trudell, S.R. Moran and T.M. Macyk. 75 pp. \$5.00

This report presents the results of a field investigation of the movement of salinized groundwater from a mined and reclaimed coal mine near Forestburg into an adjacent unmined area. The movement is considered to be an unusual occurrence resulting from a combination of a hydraulic head that is higher in the mined area than in the adjacent coal aquifer, and the presence of a thin surficial sand aquifer adjacent to the mine. The high hydraulic head results from deep ponds in the reclaimed landscape that recharge the base of the spoil.

75. RRTAC 91-1: Reclamation Research Annual Report - 1990. Reclamation Research Technical Advisory Committee. 69 pp. No longer available.

This annual report describes the expenditure of \$499 612 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program. The report lists the 70 research reports published under the program.

76. RRTAC 91-2: Winter Soil Evaluation and Mapping for Regulated Pipelines. A.G. Twardy. 43 pp. ISBN 0-7732-0874-7. \$5.00

Where possible, summer soil evaluations are preferred for pipelines. However, when winter soil evaluations must be done, this report lays out the constraints and requirements for obtaining the best possible information. Specific recommendations include: restricting evaluations to the time of day with the best light conditions; use of core- or auger-equipped drill-trucks; increased frequency of site inspections and soil analyses; and, hiring a well-qualified pedologist. The province's soils are divided into four classes, based on their difficulty of evaluation in winter: slight (most soils); moderate; high; and, severe (salt-affected soils in the Brown and Dark Brown Soil Zones).

77. RRTAC 91-3: A User Guide to Pit and Quarry Reclamation in Alberta. J.E. Green, T.D. Van Egmond, C. Wylie, I. Jones, L. Knapik and L.R. Paterson. 151 pp. ISBN 0-7732-0876-3. \$10.00

Sand and gravel pits or quarries are usually reclaimed to the original land use, especially if that was better quality agricultural or forested land. However, there are times when alternative land uses are possible. This report outlines some of the alternate land uses for reclaimed sand and gravel pits or quarries, including: agriculture, forestry, wildlife habitat, fish habitat, recreation, and residential and industrial use. The report provides a general introduction to the industry and to the reclamation process, and then outlines some of the factors to consider in selecting a land use and the methods for reclamation. The report is not a detailed guide to reclamation; it is intended to help an operator determine if a land use would be suitable and to guide him or her to other sources of information.

78. **RRTAC 91-4: Soil Physical Properties in Reclamation.** M.A. Naeth, D.J. White, D.S. Chanasyk, T.M. Macyk, C.B. Powter and D.J. Thacker. 204 pp. ISBN 0-7732-0880-1. \$10.00

This report provides information from the literature and Alberta sources on a variety of soil physical properties that can be measured on reclaimed sites. Each property is explained, measurement methods, problems, level of accuracy and common soil values are presented, and methods of dealing with the property (prevention, alleviation) are discussed. The report also contains the results of a workshop held to discuss soil physical properties and the state-of-the-art in Alberta.

79. **RRTAC 92-1: Reclamation of Sterilant Affected Sites: A Review of the Issue in Alberta.** M. Cotton and M.P. Sharma. 64 pp. ISBN 0-7732-0884-4. No longer available

This report assesses the extent of sterilant use on oil and gas leases in Alberta, identifies some of the concerns related to reclamation of sterilant affected sites and the common methods for reclaiming these sites, and outlines the methods for sampling and analyzing soils from sterilant affected sites. The report also provides an outline of a research program to address issues raised by government and industry staff.

80. **RRTAC 92-2: Reclamation Research Annual Report - 1991. Reclamation Research Technical Advisory Committee.** 55 pp. ISBN 0-7732-0888-7. No longer available.

This report describes the expenditure of \$485,065 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the five program areas, and describes the projects funded under each program. It also lists the 75 research reports that have been published to date.

81. **RRTAC 92-3: Proceedings of the Industry/Government Pipeline Reclamation Success Measurement Workshop.** R.J. Mahnic and J.A. Toogood. 62 pp. ISBN 0-7732-0886-0. \$5.00.

This report presents the results of a workshop to identify the soil and vegetation parameters that should be used to assess reclamation success on pipelines in Alberta. Six soil parameters (topsoil admixing; topsoil replacement thickness; compaction; soil loss by erosion; texture; and salinity) and six vegetation parameters (plant density; species composition; ground cover; vigour; weeds/undesirable species; and rooting characteristics) were selected as most important. Working groups discussed these parameters and presented suggested methods for assessing them in the field.

82. **RRTAC 92-4: Oil Sands Soil Reconstruction Project Five Year Summary.** HBT AGRA Limited. 109 pp. ISBN 0-7732-0875-5. \$10.00

This report documents a five year study of the effects of clay and peat amendments to oil sand tailings sand on survival and growth of trees and shrubs. Ten species (jack pine, white spruce, serviceberry, silverberry, buffaloberry, pin cherry, prickly/woods rose, Northwest poplar, green alder, and Bebb willow) were planted into tailings sand amended with three levels of peat and three levels of clay. The treatments were incorporated to a depth of 20 cm or 40 cm. Data are provided on plant survival and growth, root size and distribution, disease and small mammal damage, herbaceous cover, soil moisture, soil chemistry, and bulk density.

- 83. RRTAC 92-5: A Computer Program to Simulate Groundwater Flow and Contaminant Transport in the Vicinity of Active and Reclaimed Strip Mines: A User's Guide.** A.S. Crowe and F.W. Schwartz, SIMCO Groundwater Research Ltd. 104 pp. plus appendix. ISBN 0-7732-0877-1. **NOTE:** This report is only available from the Alberta Research Council, Publications Centre, 250 Karl Clark Road, P.O. Box 8330, Station F, EDMONTON, Alberta T6H 5R7 as ARC Information Series 119. The cost is \$20.00 and the cheque must be made out to the Alberta Research Council.

The manual describes a computer program that was developed to study the influence of coal strip mining on groundwater flow systems and to simulate the transport of generated contaminants, both spatially and in time, in the vicinity of a mine. All three phases of a strip mine can be simulated: the pre-mining regional groundwater flow system; the mining and reclamation phase; and, the post-mining water level readjustment phase. The model is sufficiently general to enable the user to specify virtually any type of geological conditions, mining scenario, and boundary conditions.

- 84. RRTAC 92-6: Alberta Drilling Waste Sump Chemistry Study. Volume I: Report (Volume II: Appendices is only available through the Alberta Research Council, Publications Centre, 250 Karl Clark Road, P.O. Box 8330, Station F, EDMONTON, Alberta T6H 5R7. The cost is \$15.00 and the cheque must be made out to the Alberta Research Council.).** T.M. Macyk, S.A. Abboud and F.I. Nikiforuk, Alberta Research Council. 217 pp. ISBN 0-7732-0879-8. \$10.00.

This study synthesizes the data from sampling and analysis of the solids and liquids found in 128 drilling waste sumps across Alberta. Drilling waste types sampled included: 72 freshwater gel, 19 invert, 27 KCl, 2 NaCl, and 8 others. Data and statistics are tabulated by waste type, depth of the drill hole, and ERCB administrative region for both the solids and the liquids. Using preliminary loading limits developed by the government/industry Drilling Waste Review Committee, the report presents information on the volume and depth of waste that could be land-spread, and the area required for landspreading. The oil and gas industry provided approximately \$585,000 for the sampling and analysis phase of this study.

- 85. RRTAC 93-1: Reclamation of Native Grasslands in Alberta: A Review of the Literature.** D.S. Kerr, L.J. Morrison and K.E. Wilkinson, Environmental Management Associates. 205 pp. plus appendices. ISBN 0-7732-0881-X. \$10.00.

A review of the literature on native grassland reclamation was conducted to summarize the current state of knowledge on reclamation and restoration efforts within Alberta. The review is comprehensive, including an overview of the regulations and guidelines governing land use on native prairie; a description of the dominant grassland ecoregions in Alberta; a review of the common disturbance types, extent and biophysical effects of disturbance on native prairie within Alberta; a description of the factors which influence the degree of disturbance and reclamation; and examples of both natural and enhanced recovery of disturbed sites through the examination of selected case studies.

- 86. RRTAC 93-2: Reclamation Research Annual Report - 1992. Reclamation Research Technical Advisory Committee.** 56 pp. ISBN 0-7732-0883-6. \$5.00.

This report describes the expenditure of \$474,705 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and the research strategies of the five programs, and describes the projects funded under each program. It also lists the 85 research reports that have been published to date.

87. **RRTAC 93-3: Catalogue of Technologies for Reducing the Environmental Impact of Fine Tailings from Oil Sand Processing.** B.J. Fuhr, Alberta Research Council, D.E. Rose, Dereng Enterprises Ltd., and D. Taplin, Komex International Ltd. 63 pp. ISBN 0-7732-0885-2. \$5.00.

A catalogue containing 22 technologies for reducing the environmental impact of fine tailings derived from oil sands has been assembled. The report consists of an introduction to oil sand processing and fine tailings generation, a simple spreadsheet for comparing the technologies, and a process summary for each technology. The technologies were not evaluated for effectiveness. Rather, a detailed set of questions was prepared that highlights the environmentally-related information a proponent should have. These questions will help to form a basis for comparisons among the technologies.

88. **RRTAC 93-4: Organic Materials as Soil Amendments in Reclamation: A Review of the Literature.** Land Resources Network Ltd. 228 pp. ISBN 0-7732-0887-9. \$10.00

A review of the literature was conducted to examine the effect of various organic materials when used as amendments to disturbed soil. Organic amendments reviewed included animal manures, crop residues, peat, wood wastes, sewage sludge, municipal yard waste, humates, vermicomposts, and spent mushroom composts. Their effects on soil chemistry, physical properties, and biology were examined. Application methods, costs, longevity of effects, and use in reclamation were also reviewed. Benefits and drawbacks of each were discussed.

89. **RRTAC 93-5: Drilling Waste Disposal.** T.M. Macyk and S.A. Abboud, Alberta Research Council. 125 pp. ISBN 0-7732-0889-5. \$10.00

An overall perspective and description of the steps involved in the management and land-based disposal of drilling wastes in Alberta. A computer program, available from the Alberta Research Council, has been written to support the data management required for proper disposal. A field manual is in preparation. These three information sources provide technical support for the Energy Resources Conservation Board's Guide G-50: Drilling Waste Management.

90. **RRTAC 93-6: Mapping and Characterization of Cutover Peatlands for Reclamation Planning.** L.W. Turchenek, Alberta Research Council, W.S. Tedder, Alberta Agriculture, Food and Rural Development, and R. Krzanowski, Alberta Research Council. 100 pp. ISBN 0-7732-6038-2. \$5.00

The report presents a methodology for cost-effective soil survey and sampling of cutover peatlands. It also presents baseline chemical information and data interpretation for peat materials from a cutover peatland site. The report provides background information on classifying and describing peatlands. This information can be used to develop reclamation plans.

91. **RRTAC 93-7: Soil Series Information for Reclamation Planning in Alberta.** Pedocan Land Evaluation Ltd. Various pagings. ISBN 0-7732-6041-2. \$10.00

This manual has been published to provide conservation and reclamation planners with information and guidelines to help understand and use soil inventory data. The soil series in the manual correspond to those in the Generation 2 Alberta Soil Names File. Part 1 of the manual describes the terminology used in soil surveys and presents the assumptions and conventions upon which the interpretations for each soil series are based. Part 2 presents typical data and interpretations for each soil series.

92. **RRTAC 93-8: Oil Sands Sludge Dewatering by Freeze-Thaw and Evapotranspiration.** R.L. Johnson, P. Bork, W. H. James and L. Koverny, Alberta Environmental Centre. 247 pp. ISBN 0-7732-6042-0. \$10.00

This report presents data from a series of laboratory and field experiments designed to evaluate the removal of water from oil sands sludge. A number of plant species were evaluated and two, reed canary grass and western dock, were found to remove a significant amount of water through evapotranspiration. Freeze-thaw cycles were also found to remove water from both sand-sludge mixtures and pure sludge. A combination of freeze-thaw and biological dewatering using plants was found to increase solids content from 30% to 80%. At 80% solids the sludge had a shear strength of 120 kPa and could support machine traffic. These studies prompted further field work.

93. **RRTAC 93-9: Native Legumes for Reclamation in Alberta.** A. Smreciu, Wild Rose Consulting Inc. 94 pp. ISBN 0-7732-0643-9. \$5.00

Seeds from *Astragalus* (milkvetches), *Hedysarum* (sweetbrooms), *Lupinus* (lupins), and *Oxytropis* (locoweeds) were collected from the mountains and foothills region of Alberta, from Waterton Lakes National Park to Grande Cache. The species were tested for germination and seedlings were established and evaluated for three growing seasons in Vegreville. The species were evaluated based on survival, growth and development, and yield. *Astragalus alpinus* was selected as the most promising species. *Oxytropis monticola* and *Oxytropis splendens* were also recommended.

94. **RRTAC 93-10: Proceedings of the Alberta Wellsite Reclamation Criteria Workshop.** R.J. Mahnic, Communiplan Inc., L.J. Knapik and T.R. Bossenberry, Pedocan Land Evaluation Ltd., and G.C. Mott, G.C. Mott Associates. Various Pagings. ISBN 0-7732-0644-7. \$10.00

This report summarizes government, industry and public comments received before and during a two-day workshop held to discuss the *Reclamation Criteria for Wellsites and Associated Facilities*. The information in the report was used to revise the Criteria for use from 1994 onward.

95. **RRTAC 93-11: Salt Movement in Disturbed Soils.** N.M. Finlayson, Land Resources Network. 61 pp. ISBN 0-7732-6045-5. \$5.00

The report reviews the literature regarding the movement of salts down or up in the soil profile following surface disturbance. The objective was to find out if salts in the upper 50 cm of a soil profile would return to pre-disturbance levels. If they do, special soil handling requirements may not be needed for saline soils when pipelining. There were few studies on pipelines so the majority of the report focuses on mining and deep plowing studies. The results varied between soil zones. More pipeline specific work is required.

96. **RRTAC 93-12: Reclamation Techniques for Soils Treated with Non-Selective Residual Herbicides (Soil Sterilants):** M.M. Cotton, Artemis Consulting Inc. and M.P. Sharma, Alberta Environmental Centre. 84 pp. ISBN 0-7732-6046-3. \$5.00

Several soil amendments were examined for their effectiveness at inactivating herbicide residues under controlled and field conditions. The influence of herbicide and amendment ratios; soil type, and number of incorporations on the effectiveness of the amendments were considered. Bromacil, tebuthiuron, atrazine and diuron were the herbicides tested. Activated charcoal and manure were the two best treatments, and when combined provided crop protection and stimulated crop growth. The quality (age) of manure affected its ability to protect crops.

